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Northwestern Univ, Evanston, Ill Dept of Civil Engineering

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In an effort to quantitatively evaluate the effects of the settling-basin concept on the water quality associated with a typical disposal site for polluted maintenance dredgings, as well as to assess the fate of pollutants during a typical dredging and disposal cycle, an extensive sampling and testing program was carried out.

Based upon the measurements and analysis performed, it was concluded that most of the polluting substances contained in the dredge spoil are retained in the diked enclosure, and only a small fraction of the pollutants are discharged via the overflow weir into the ambient river water. The large reductions in the concentrations of pollutants is primarily attributable to the fact that they tend to associate with the solid particles, which settle out of suspension and are retained within the disposal area. The concentrations of most parameters were reduced more than 95%, but the more soluble substances were less affected by the settling process and they were discharged with less change in their input concentrations.

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Water Quality Study for a Dredgings Disposal Area

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The need to protect the ecology of the Great Lakes and the other waterways of the United States has led to a variety of problems concerned with the dredging and disposal of increasing volumes of polluted dredge spoil in areas of high population density and industrial development. One commonly used alternative to open water disposal is to place these polluted sediments in diked containment areas to form landfills of marginal value. However, due to the high costs involved, the scarcity of land, and other environmental and economic considerations, these landfills should desirably serve some useful purpose. Accordingly, this study was directed toward evaluating quantitatively the engineering characteristics of dredged materials as they affect their potential usefulness in a landfill.

Francis T. Mayo, Director
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SUMMARY

In an effort to quantitatively evaluate the effect of the settling-basin concept on the water quality associated with a typical disposal site for polluted maintenance dredgings, as well as to assess the fate of pollutants during a typical dredging and disposal cycle, an extensive sampling and testing program was carried out between August 20 and December 20 of 1972 at the Penn 7 dredgings disposal area in Toledo, Ohio. Over 100 samples of slurry influent, overflow effluent, groundwater, ambient river water, bottom sediments, and material from the hopper bins and overflow waters were collected and analyzed for standard physical, chemical, and microbiological parameters. In addition, meteorological and hydrological recording instruments were installed at and near the diked enclosure to investigate the water quantity budget of the disposal site.

Based upon the measurements and analyses performed, it was concluded that most of the polluting substances contained in the dredge spoil are retained in the diked enclosure, and only a small fraction of the pollutants are discharged via the overflow weir into the ambient river water. The large reductions in the concentrations of pollutants is primarily attributable to the fact that they tend to associate with the solid particles, which settle out of suspension and are retained within the disposal area. The concentrations of most parameters were reduced more than 95%, but the more soluble substances were less affected by the settling process and they were discharged with less change in their input concentrations. In general, the water quality of the effluent resembled that of the ambient river water used as a carrier to pump the

dredgings in slurry form from the hopper dredge into the disposal area. Apprpximately 425,000 cubic feet (12,000 cubic meters) of overflow water is discharged daily from the disposal area during periods of dredging operations. Precipitation and evaporation have little effect on the water budget, and it appears that little water drains into the underlying foundation soils.

The one adverse change that occurred in the water quality parameters was the large increase in nitrate nitrogen between influent and effluent. The average nitrate concentrations increased from about 0.7 ppm to approximately 8 ppm due to the process of nitrification that took place in the aerobic conditions of the disposal area. The dredge slurries apparently contain high concentrations of total and organic nitrogen which undergo ammonification and nitrification processes due to a change from anaerobic to aerobic conditions; the very soluble nitrate ion therefore shows up in the effluent water that passes over the weir. This could be interpreted as increasing the eutrophication process of the harbor area adjacent to the diked enclosure. However, the practice of open dumping would contribute far more nitrogen and other nutrients to the ambient waters than does the process of confined disposal. Since the dredged materials contained in a disposal area represent concentrated sources of various pollutants, future studies should be conducted to investigate the extent to which these pollutants may leach into the groundwater.

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Several discussions regarding the water quality problems associated with dredging and disposal operations were shared with Dr. Emil Mosonyi and Dr. Edward R. Hermann.

Many other persons, too numerous to mention individually, have contributed in various ways to achieve the results contained in this report, and their efforts are sincerely appreciated.

INTRODUCTION

The sediments in the harbors and waterways of most industrialized countries contain a variety of contaminants that vary from location to location and from time to time, depending upon the siting of industrial plants, the nature of the wastes that are discharged, the flow conditions in the river or channel, and the dispersion characteristics of the contaminant. As a consequence, many of these sediments, when dredged to maintain shipping channels, are classified as "polluted" and open water disposal is prohibited; one feasible alternate disposal method (Corps of Engineers, Buffalo District, 1969) is to deposit these polluted dredgings in diked containment areas. In order to evaluate the effectiveness of this disposal procedure, a program was undertaken to study the water quality effects associated with the disposal of polluted dredgings in a typical diked containment area over a four-month period of time.

Although a variety of techniques are used to dredge bottom sediments and deposit them in a prescribed disposal site, the procedure employed in this study involved the hydraulic placement of dredged materials by means of a hopper dredge. In such a case the sediments are collected in the hopper of the dredge during the dredging operation and then pumped, together with large quantities of ambient water, into the containment area. In general, the solids settle out of suspension and the supernatant water passes over a weir and is returned to the river. During the course of this study attempts were made to monitor the quality and quantity of the waters and dredging slurries that entered and exited the diked area.

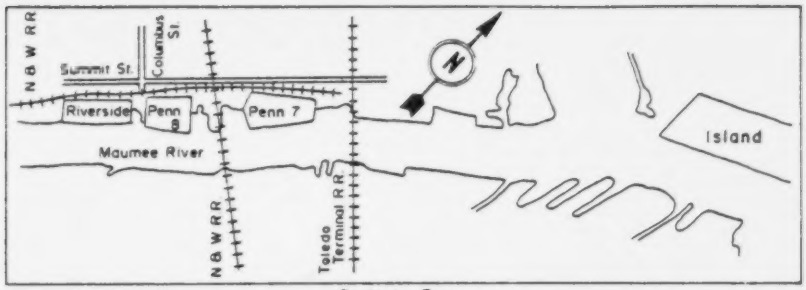
In addition, chemical and bacteriological analyses were conducted on similar materials sampled at various stages during the dredging and disposal cycle and on groundwater samples taken from wells in the foundation soils underlying the disposal site.

LOCATION OF TEST SITE

The harbor of Toledo, Ohio, lies at the mouth of the Maumee River, which drains over 6500 square miles of bordering lands in Indiana, Michigan, and Ohio. Much of the basin consists of flatlands, and more than 90 percent of this land is agricultural. The soils are relatively impermeable, and stream flows are low during dry weather. However, when the rainfall is heavy, the waters tend to back up in the tributaries and flood these flatlands, and, as the flow recedes, heavy loads of silt and finely divided organic matter are washed into the streams, along with nutrients and other litter in colloidal form.

It is generally recognized that the major long-term pollution of the Maumee River and its associated streams comes from agricultural sources. In its normal flow the Maumee River carries a heavy load of suspended sediments, which, together with its rate of flow, is conducive to a naturally high turbidity. Most of the sediments emanate from river bank and land sheet erosion, and only a small percentage is attributable to industrial sources. Two of the principal crops of the area are corn and soybeans, both of which leave the soil bare and open to erosion during the winter. Lake level fluctuations and wave action tend to keep colloidal particles in suspension and to redistribute the fine materials.

The field monitoring program described herein was conducted at the Penn 7 disposal site, which, as shown in Figure 1, is located to the east of Toledo along the northwest bank of the Maumee River in the vicinity



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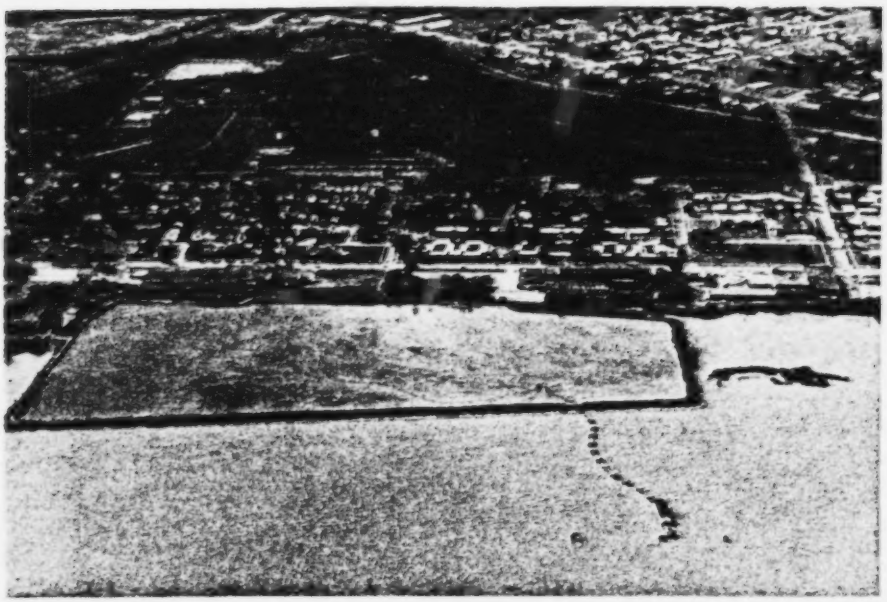

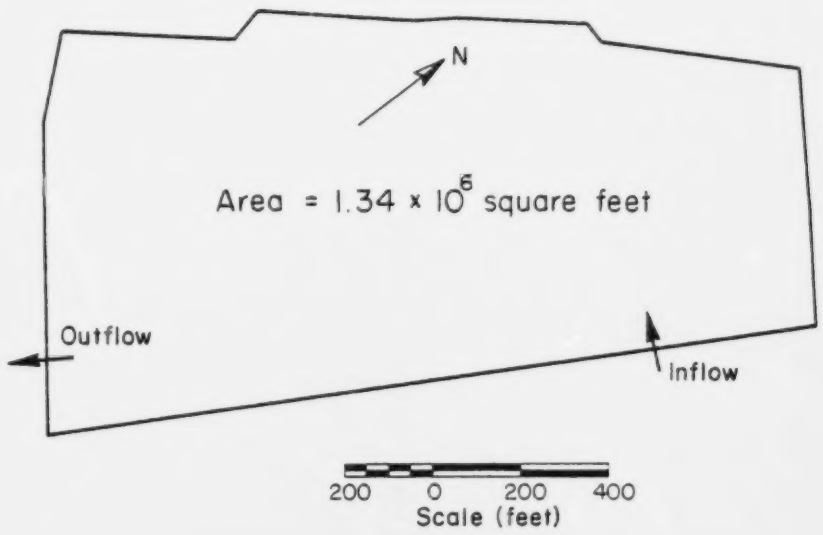

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Scale (feet)

Figure 1. Plan View of Penn 7 Disposal Site

of several other disposal sites. The dimensions of the site are approximately 800 feet (250 meters) by 1700 feet (520 meters), and it encloses an area of about 31 acres (1.34 million square feet or 0.125 million square meters) with an average depth of about 15 feet (4.5 meters), thereby giving it a storage capacity of about 0.75 million cubic yards (0.57 million cubic meters). The distance between the inlet pipe and the overflow weir is approximately 1300 feet (400 meters). In general, the site is underlain at shallow depths (10 feet or 3 meters) by sandy or silty clays, but the deeper soils manifest a wide range of variability (Krizek and Salem, 1974); coefficients of permeability ranged from about 10^{-4} to 10^{-6} cm/sec for the shallow deposits and from about 10^{-3} to 10^{-5} cm/sec for the deeper soils.

DESIGN OF STUDY

This investigation consists essentially of two parts. In the first part the input slurry to a disposal site is characterized according to its pollution loading and the effectiveness of a diked containment area to retain the contaminants in the dredge spoil and preserve the quality of the water returning to the river is examined by means of an extensive sampling and testing program of influent and effluent materials; also studied is the change in the quality of the groundwater beneath a disposal site. The second part of the study is directed toward evaluating, insofar as possible, the quantitative aspects of the water budget for a typical disposal site.

The diked containment area is regarded as a closed system, and its boundaries are considered to be the four earth sidewalls, the original ground before deposition of any dredgings, and the surface of the water at any given time. Accordingly, the water budget of the diked area can

be described in terms of the following variables:

- I Influent of slurry pumped from hopper dredge (volume per unit time)
- O Outflow discharged over a control weir (volume per unit time)
- P Precipitation (volume per unit time)
- E Evaporation (volume per unit time)
- D Drainage into the groundwater or through the dikes (volume per unit time)
- S Storage of water within the diked containment area at any given time (volume)

Hence, at any point in the deposition process the time rate of water storage, $\frac{\Delta S}{\Delta T}$, may be expressed as

$$\frac{\Delta S}{\Delta T} = (I + P) - (O + E + D) \quad . \qquad (1)$$

However, only four of the six budget variables are known with any degree of accuracy. The outflow quantity, O, was measured and recorded by a flow measuring system installed at the discharge weir. Precipitation and evaporation, P and E, were monitored by a recording rain gage and a recording evaporimeter installed nearby at the Toledo Field Office of the Corps of Engineers. The quantity of water stored, S, or time rate of change of water stored, $\Delta S/\Delta T$, were obtained from measurements of the water level, which was incrementally controlled by changing the height of the discharge weir. It was planned to obtain the inflow quantity, I, from Corps of Engineers records of pumping operations, but, as explained in Appendix J, these records do not reflect the quantities of flush water used to clean the hopper dredge and pipeline before and after pumping operations; consequently, I is not known with any degree of certainty. The sixth variable, D, was not measured (this variable was originally intended to play the role of the balance term in the water budget). Although it is possible that some slight runoff could enter the diked containment area, surface runoff was assumed to be negligible.

This study spanned the period from August 20 to December 20, 1972, during which time dredgings were pumped almost continuously (about 8 loads per day, except on Sundays) into the Penn 7 area. However, it was not until October 19, 1972 that the water level in the disposal site reached the point where effluent began to flow over the weir; then, on November 13, 1972 the flow meter malfunctioned. Although data for the water quality study were accumulated over virtually the entire 4-month period, the collection of water quantity data to establish the water budget was limited to a 26-day period for all practical purposes.

WATER QUALITY EVALUATION

A sampling program was undertaken to characterize, insofar as reasonably possible, the quality of the dredged materials and associated waters at various stages during the dredging and disposal cycle. Specifically included in this characterization are samples of (a) bottom sediments, (b) water from the overflow of the hopper dredge, (c) material from the bin of the hopper dredge, (d) slurry from the inflow pipe to the disposal area, (e) water from the overflow weir of the disposal area, (f) river water, and (g) groundwater, but emphasis was given to the influent and effluent samples from the inflow pipe and overflow weir.

Sampling Program

Since dredgings were pumped into Penn 7 during 107 days over a 123 day period at a rate of approximately 8 loads per day, there were about 850 individual inputs of varying quality and quantity. Ideally, the influent and effluent materials should have been sampled several times during each pumping operation, since the nature of the dredgings varied considerably. However, this would have posed an impossible task of sampling and analysis, and a random sampling approach was therefore pursued. One-gallon (3.8-liter) samples were normally collected, packed

in ice chests, and transported to the laboratory, where they were stored at approximately 4°C until tested. Special handling was given to the samples to be subjected to bacteriological tests, and such tests were conducted within 24 hours.

Special efforts were made to evaluate the adequacy of the sampling procedures and the statistical significance of the resulting data. In certain cases samples were taken (a) simultaneously from different points in the slurry jet emerging from the inflow pipe, (b) from the same load at five minute intervals, (c) from each load in any given day, and (d) from two or three loads every day for four or five consecutive days. Variability tests on these groups of samples were performed to assess the adequacy of a sampling program wherein replicate samples of slurry inflow were collected randomly once or twice a week; however, no samples were taken during the extreme beginning or end of a pumping cycle, since such periods would likely be dominated by flush water and thereby yield grossly unrepresentative samples. Variations in samples from the overflow weir were relatively small compared to variations in slurry samples, and fewer samples were therefore taken. Initial groundwater samples were taken prior to the deposition of any dredgings in the area, and follow-up sets of samples were taken about one year after dredging disposal had commenced and after the site was filled. An extremely limited number of samples was obtained during each of the other stages of the dredging and disposal operation, so the results must be assessed accordingly. A brief description of the source and nature of each sample, together with its designation and the time at which it was taken, is given in Appendix A.

Laboratory Analyses

The influent into the diked disposal area was expected to have a high solids content consisting of silt, clay, and organic matter. In addition, high levels of phosphorus and nitrogen were expected, since the sediments originate in agricultural areas. Many trace metals and some heavy metals and other toxic substances were anticipated; and, due to the industrial nature of the local surroundings, it was likely that oil, grease, and other persistent organics would be found. Although it was expected that most of the solids and insoluble substances would be retained in the diked area, it is possible that all of these contaminants would be found in trace quantities in the effluent with the more soluble substances in higher concentrations. Accordingly, the fairly comprehensive set of analyses outlined below was undertaken to quantitatively evaluate these aspects of the problem; the testing procedures are explained in Appendix B, and the results are given in Appendices C, D, and E. In addition, some bacteriological test data are reported in Appendix E, and the results from a gas chromatographic analysis on the solids and water portions of one sample to determine the presence of chlorinated organic compounds are given in Appendix F.

General Water Quality Parameters

Total Solids
Dissolved Non-volatile Solids
Suspended Non-volatile Solids
Hydrogen Ion Concentration (pH)
Total Silica

Nutrients

Total Nitrogen
Ammonia Nitrogen
Nitrate Nitrogen
Nitrite Nitrogen
Total Phosphate
Soluble Phosphate

Organics

Biochemical Oxygen Demand (BOD)
Chemical Oxygen Demand (COD)
Total Volatile Solids
Suspended Volatile Solids
Dissolved Volatile Solids
Oil and Grease

Metals

Cadmium
Calcium
Copper
Iron
Lead
Manganese
Potassium
Sodium
Zinc

Sample Variability

During this sampling program, several variability tests were conducted on the influent materials by sampling periodically during some particular phase of the disposal operation. In one series of tests samples were taken at five minute intervals after pumping started until it was almost completed; the results of this test, shown in Figure 2, indicated that the concentrations of several constituents in the sample varied considerably, but irregularly, with a slightly decreasing trend as pumping continued. A similar series of variability tests were performed on samples taken intermittently over a period of 14 hours, and these results are shown in Figure 3; again, no clearly predictable patterns were detected. Based on the results of these tests, it was decided that replicate samples collected randomly (except to avoid the extreme starting or ending periods of a pump-out cycle) once or twice a week would yield representative samples for the determination of influent quality.

Comparison of Influent-Effluent Quality

The detailed data from the chemical analyses on influent slurry samples and effluent water samples are presented in Appendix C, and these results are averaged on a daily basis (that is, the measured values for all samples taken in any given day were averaged) and plotted on the graphs contained in Appendix D. These daily averages were then averaged over the duration of field test program, as illustrated in Appendix D, and the overall results are summarized in Table 1. It can readily be seen that the diked containment area serves effectively to retain a substantial portion of virtually all pollutants. Of the sixteen parameters listed in Table 1, the concentrations of ten were reduced by well over 95% and five were reduced by values ranging from 45% to 90%; nitrate nitrogen showed a more than ten-fold increase, but this was not unexpected.

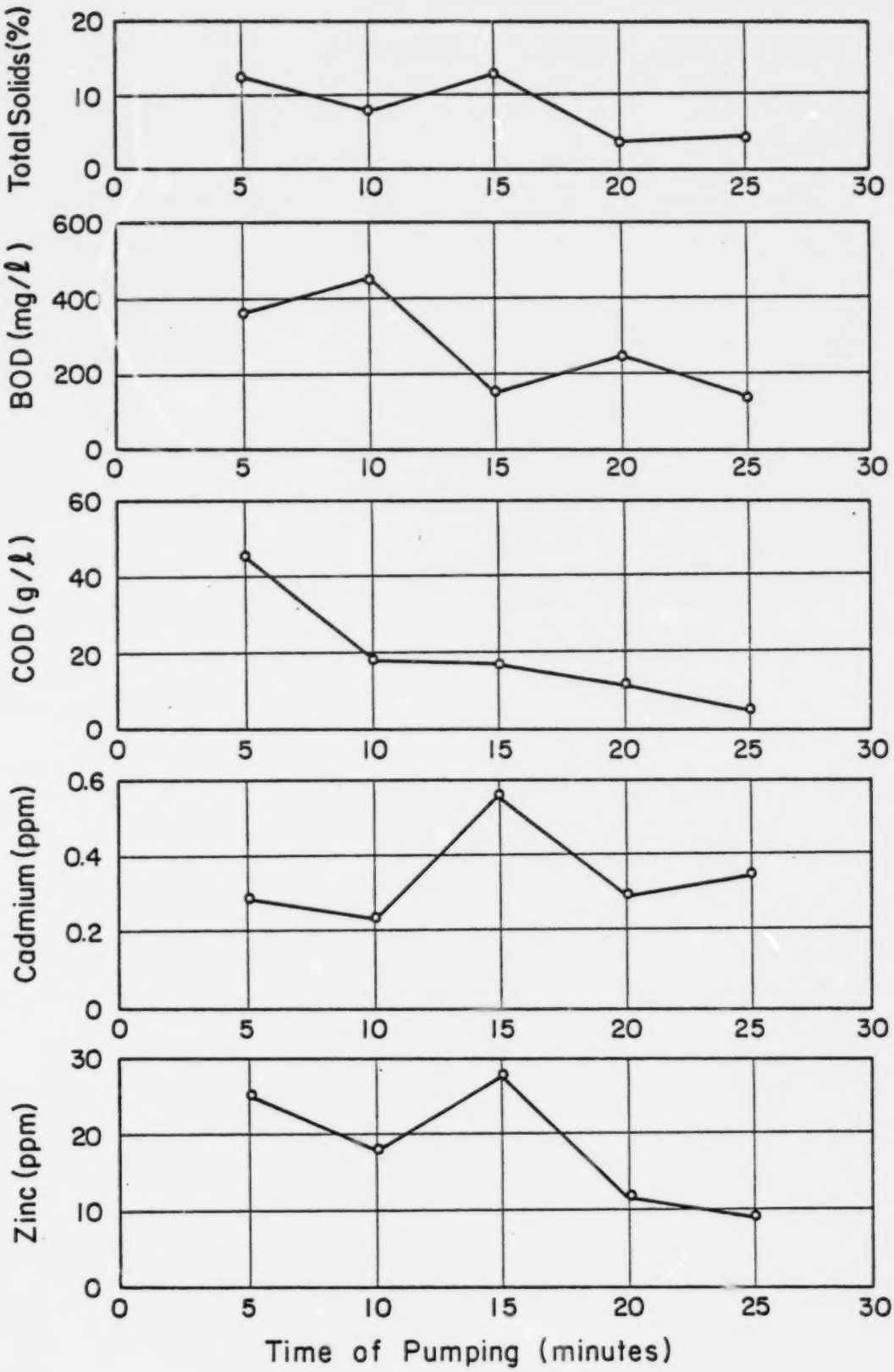


Figure 2. Sample Variability During Typical Pump-Out

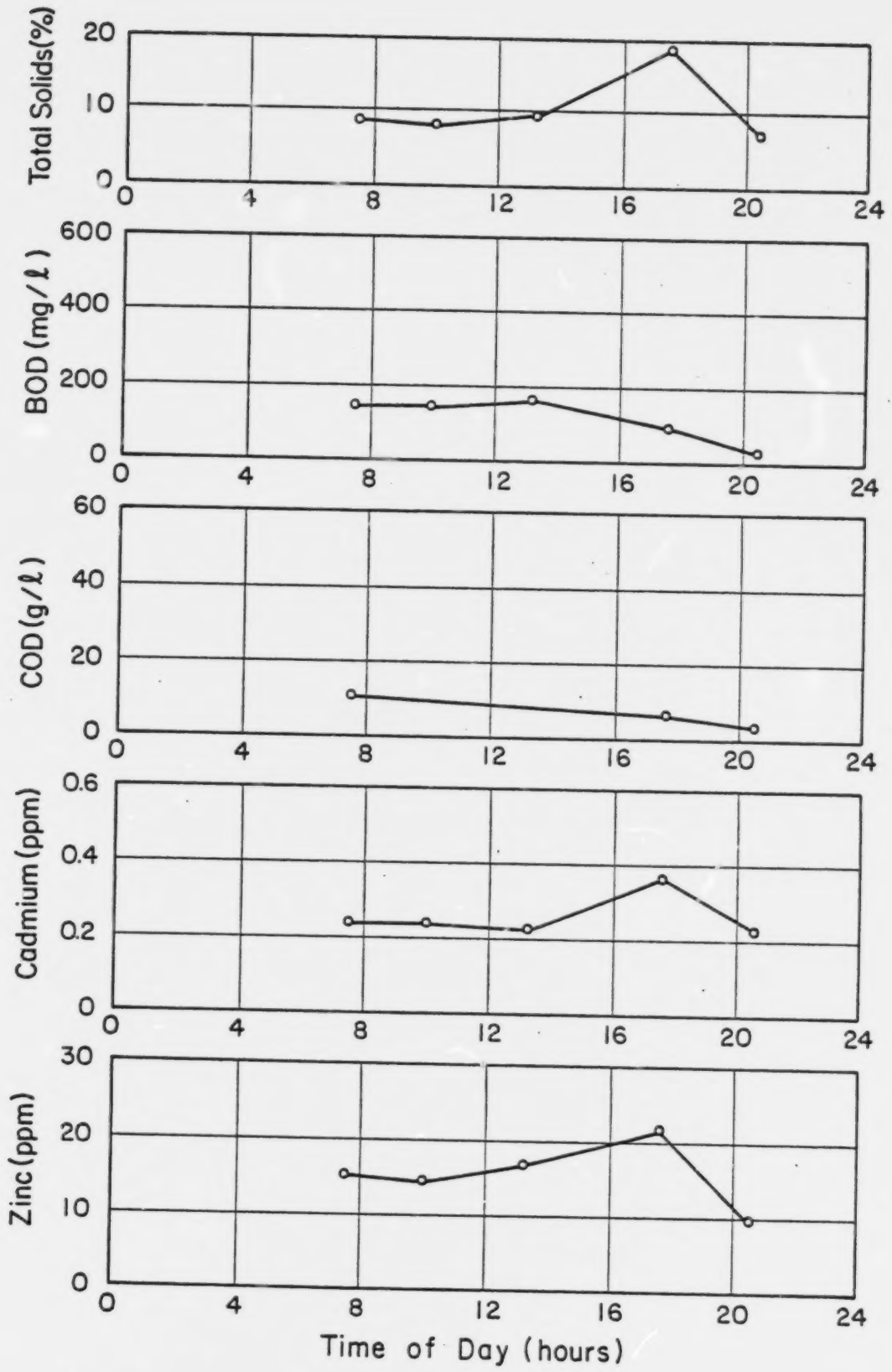


Figure 3. Sample Variability During Typical Series of Five Loads

Table 1

Comparison of Average Influent-Effluent Concentrations

Parameter	Units	Concentration		Percent Increase (+) or Decrease (-)
		Influent	Effluent	
Total Solids	%	14.9	0.043	-99.7
Total Silica	%	11.5	0.014	-99.9
Chemical Oxygen Demand	mg/ℓ	15,000	135	-99.1
Biological Oxygen Demand	mg/ℓ	334	5.3	-98.4
Total Phosphate	ppm	344	4.5	-98.7
Nitrite Nitrogen	ppm	0.045	0.010	-77.8
Nitrate Nitrogen	ppm	0.7	8.0	+1145
Cadmium	ppm	0.66	0.24	-63.5
Calcium	ppm	4000	100	-97.5
Copper	ppm	7.1	3.9	-45.0
Iron	ppm	3000	5.6	-99.8
Lead	ppm	10.3	5.7	-45.0
Manganese	ppm	63	2.1	-96.7
Potassium	ppm	525	6.5	-98.8
Sodium	ppm	120	15	-87.5
Zinc	ppm	17	0.7	-95.9

Fate of Pollutants During Dredging and Disposal Cycle

Table 2 places the influent-effluent comparisons described above in the broader context of the overall dredging and disposal cycle. In addition to the extensive sampling program undertaken for influent and effluent samples, a limited number of samples were taken from the harbor bottom before dredging, from the hopper of the dredge and from the hopper overflow during the dredging operation, from the ambient river water away from the disposal site, and from the groundwater in the vicinity of the disposal site. Within the framework of these data (first averaged on a daily basis, and then an average of the daily averages), the following conclusions may be advanced:

1. The concentrations of pollutants are very high in the bottom sedi-sediments, the materials in the hopper bin, and the water that overflows the hopper bins as they become filled.

2. Although still quite high, the concentrations of pollutants in the slurry deposited in the containment area are reduced somewhat by the addition of ambient river water, which acts as a carrier to pump the dredgings into the diked enclosure; however, the contaminants appear to reflect agricultural deposits rather than industrial or sewage wastes.

3. With the exception of nitrate nitrogen, a marked reduction in pollutant concentrations occurs before the effluent water is discharged over the weir back into the river, and the quality of the effluent water is similar to that of the river water.

4. The quality of the groundwater is slightly worse than either the river water or the effluent water.

Representativeness of Sample

In any study of the type reported herein, the representativeness of any given sample or the statistical characteristics of a group of samples is always of considerable concern. One evaluation of this type can be appreciated by examining the graphical representations of the data given in Appendix D and the summary given in Table 1 of the overall average values of these data on a daily average basis (that is, the measured

Table 2. Average Values of Chemical Parameters at Various Stages of Dredging and Disposal Cycle

Chemical Parameter	Units	Average Value						
		Bottom Sediments	Hopper Overflow	Hopper Bin	Slurry Inflow	Dike Overflow	River Water	Ground Water
Total Solids	%	33.031	19.106	43.508	14.890	0.046	0.023	0.228
Total Nonvolatile Solids	%	31.858	18.459	42.072	13.909	0.036	0.019	0.179
Total Volatile Solids	%	1.173	0.647	1.437	1.116	0.012	0.004	0.073
Nonvolatile Suspended Solids	%	31.832	18.431	42.044	13.858		0.019	0.122
Volatile Suspended Solids	%	1.159	0.631	1.425	1.099		0.004	0.032
Nonvolatile Dissolved Solids	%	0.026	0.028	0.028	0.051			0.057
Volatile Dissolved Solids	%	0.014	0.016	0.012	0.017			0.041
Total Silica	%	26.203	14.294	35.371	11.50	0.014	0.012	0.079
Chemical Oxygen Demand	mg/l	31,100			15,000	135	123	187
Biochemical Oxygen Demand	mg/l		380		334	5.3	2	4.1
Total Nitrogen	ppm				135			13.5
Ammonia Nitrogen	ppm				87			13.5
Nitrite Nitrogen	ppm	0.038	0.016	0.013	0.045	0.01	0.01	0.026
Nitrate Nitrogen	ppm	0.402	0.176	0.142	0.694	8.03	7.8	11.1
Total Phosphate	ppm	632		476	344	4.5	3.9	7.4
Soluble Phosphate	ppm	0.112		0.065	0.146			
Cadmium	ppm	1.57	1.85	1.39	0.66	0.24	0.30	0.33
Calcium	ppm	7,400	6,600	6,600	4,000	101	75	273
Copper	ppm	8.4	9.2	8.8	7.1	3.9	7.5	6.2
Iron	ppm	4,400	3,700	3,600	3,000	5.5	7.5	65.5
Lead	ppm	14.2	11.5	15.6	10.2	5.7	6.0	6.7
Manganese	ppm	115.4	92.3	137.3	62.8	2.1	3.0	3.2
Potassium	ppm	295	335	240	525	6.5	9.9	26.4
Sodium	ppm	121.8	187.5	164.3	121.2	15.1	10.2	38.1
Zinc	ppm	33.9	29.4	39.8	17.1	0.7	0.8	1.12
Oil and Grease	%				0.19			
pH		6.8	6.9	7.0	6.9	6.7	6.8	6.7

values for all samples taken in any given day were averaged and plotted as a single value for that day, and then these daily averages were averaged to obtain an overall average). Another type of statistical evaluation may be carried out by simply treating the entire collection of samples during any specified period of time as an entity and calculating statistical parameters of interest.

This was done for 75 samples of dredging slurries obtained from the end of the discharge pipe as the materials were pumped into the Penn 7 disposal area duing the months of August through December of 1972; these samples are the same as those influent samples for which the daily averages are plotted in Figures D-1 through D-16. The statistical parameters for these samples were calculated on the basis that the distributions are normal (but this assumed normality was not checked), and the results are shown in Table 3. It can be readily seen that the range of values determined for any given parameter is generally quite large, and a particular sample can be considered representative of dredgings from the Toledo area during a 4-month period only in a statistical sense.

A comparison of the average or mean values obtained for each parameter by subjecting the same data to the two different types of analysis described above is given in Table 4; despite the different weighting schemes for a given item of information, the agreement manifested in Table 4 is quite good. When the information listed in Table 4 is viewed in terms of the pollution criteria given in Table 5, the mean values of volatile solids, COD, lead, and zinc, when converted to a dry weight basis, exceed the specified limiting concentrations, thereby ascertaining that these dredgings are "polluted"; since no measurements of total Kjeldahl nitrogen, oil and grease, or mercury were made, definite evaluations regarding their role as "pollution parameters" can not be advanced.

Table 3. Statistical Character of Samples Tested

Parameter	Units	Number of Samples	Range	Mean	Standard Deviation	Standard Deviation of Sample Mean	Coefficient of Variation
Total Solids	%	75	1.5 - 47.5	18.2	11.91	1.38	0.65
Non-volatile Suspended Solids	%	74	1.3 - 46.0	17.1	11.29	1.31	0.66
Volatile Suspended Solids	%	74	0.04 - 4.19	1.14	0.574	0.067	0.50
Non-volatile Dissolved Solids	%	74	0.001 - 0.047	0.029	0.0118	0.0014	0.41
Volatile Dissolved Solids	%	74	0 - 0.038	0.014	0.0080	0.0009	0.57
Silica	%	60	0.9 - 36.0	12.0	8.98	1.16	0.75
pH		58	6.4 - 7.1	6.87	0.147	0.019	0.003
COD	g/ℓ	49	0.9 - 29.4	15.0	10.39	1.48	0.69
BOD	mg/ℓ	52	16 - 1940	318	407.5	56.52	1.28
Nitrate	ppm	62	0.09 - 5.60	0.56	1.038	0.132	1.85
Nitrite	ppm	61	<0.004 - 0.266	0.040	0.0470	0.006	1.00
Total Phosphate	ppm	47	46 - 801	317	205.7	29.99	0.65
Soluble Phosphate	ppm	43	<0.04 - 0.30	0.15	0.059	0.009	0.39
Cadmium	ppm	62	<0.1 - 1.8	0.6	0.49	0.06	0.82
Calcium	ppt	62	0.5 - 11.7	4.1	2.05	0.26	0.50
Copper	ppm	62	<5 - 57	9	8.3	1.05	0.92
Iron	ppt	62	0.6 - 6.2	2.9	1.64	0.21	0.57
Lead	ppm	62	<7 - 43	12	5.5	0.70	0.46
Manganese	ppm	62	10 - 230	63	36.7	4.66	0.58
Potassium	ppm	61	40 - 1210	489	303.1	38,8	0.62
Sodium	ppm	62	30 - 260	102	53.5	6.80	0.53
Zinc	ppm	62	5.6 - 57.2	19.3	12.49	1.59	0.65

Table 4

Mean Value Comparisons for Different Averaging Techniques

Parameter	Units	Mean Value	
		Daily Averages	Individual Samples
Total Solids	%	14.9	18.2
Silica	%	11.5	12.0
COD	g/ℓ	15.0	15.0
BOD	mg/ℓ	334	318
Nitrate	ppm	0.70	0.56
Nitrite	ppm	0.045	0.040
Total Phosphate	ppm	344	317
Cadmium	ppm	0.66	0.60
Calcium	ppt	4.0	4.1
Copper	ppm	7.1	9.0
Iron	ppt	3.0	2.9
Lead	ppm	10.3	12.0
Manganese	ppm	63	63
Potassium	ppm	525	489
Sodium	ppm	120	102
Zinc	ppm	17.0	19.3

Table 5. Guidelines for Limiting Concentrations of Various Pollutants in Bottom Sediments

Sediments in Fresh and Marine Waters	Concentration Percent (Dry Weight Basis)
Volatile Solids	6.0
Chemical Oxygen Demand (COD)	5.0
Total Kjeldahl Nitrogen	0.10
Oil and Grease	0.15
Mercury	0.0001
Lead	0.005
Zinc	0.005

To determine whether or not any of the measured parameters are related, a rank correlation was calculated, and these results, together with their associated significance at the 0.01 and 0.10 levels, are given in Table 6. As can be seen, a number of parameters appear to be related. The indicated relationship between COD and total solids is not unexpected, since there are certain oxidizable anions, cations, and non-volatile organics that would be detected in the COD test. One would expect that only some of these species would be oxidized biochemically in the BOD test, and therefore it is logical to observe less correspondence between total solids and BOD. The relationship between COD and BOD is well known and anticipated, because BOD measures those chemicals that can be oxidized biochemically and COD measures all chemicals that can be oxidized. However, the relationships between total solids and total and soluble phosphate and between COD and total and soluble phosphate are difficult to explain.

In the cases of nitrite with nitrate and total phosphate with soluble phosphate, interactions would normally be expected. A strong correlation (significant at less than the 0.001 level) was found between total solids and silica; however, this is logical because the silica content (12.0%) represents a major portion (about 75%) of the total solids (18.2%) and,

Table 6. Rank Correlation of Measured Parameters

Parameters	Number of Samples	Rank Correlation Coefficient	Significance At 0.01 Level	Significance At 0.10 Level
Total Solids vs Silica	60	+ 0.99	Yes	Yes
Total Solids vs COD	49	+ 0.59	Yes	Yes
Total Solids vs BOD	52	+ 0.37	Yes	Yes
Total Solids vs Nitrite	61	- 0.27	---	Yes
Total Solids vs Nitrate	62	- 0.26	---	Yes
Total Solids vs Total Phosphate	48	+ 0.72	Yes	Yes
Total Solids vs Soluble Phosphate	43	- 0.59	Yes	Yes
COD vs BOD	44	+ 0.79	Yes	Yes
COD vs Nitrite	48	- 0.15	---	---
COD vs Nitrate	48	- 0.44	Yes	Yes
COD vs Total Phosphate	35	+ 0.53	Yes	Yes
COD vs Soluble Phosphate	31	- 0.17	---	---
BOD vs Nitrite	50	- 0.21	---	---
BOD vs Nitrate	50	- 0.29	---	Yes
BOD vs Total Phosphate	39	+ 0.37	---	Yes
BOD vs Soluble Phosphate	35	- 0.08	---	---
Nitrite vs Nitrate	63	+ 0.51	Yes	Yes
Nitrite vs Total Phosphate	47	- 0.37	---	Yes
Nitrite vs Soluble Phosphate	42	+ 0.10	---	---
Nitrate vs Total Phosphate	48	- 0.37	---	Yes
Nitrate vs Soluble Phosphate	43	+ 0.16	---	---
Total Phosphate vs Soluble Phosphate	40	- 0.45	Yes	Yes

according to the analysis scheme outlined in Appendix B, the silica analysis was performed on the portion of the sample that was used to determine the total solids. Since the total solids and silica are related, it seems logical to expect that the metals would be interrelated. The degree of correspondence between metal ions was measured by determining the coefficient of concordance. Using 62 samples and testing 9 metals, the resulting coefficient was 11.1, which is highly significant. Thus, there appears to be little difference in the overall composition of metal ions in these samples collected from different locations within the Toledo area.

Pesticides

Gas chromatograph analyses (Appendix F) were conducted on the solid and supernatant phases of one slurry sample to check for the presence of pesticide materials. Based on this very limited amount of data, it appears that significant amounts of chlorinated organic compounds are present in dredged sediments or suspended solids, but, due to their insolubility, only a trace of these compounds was detected in the supernatant water. A similar conclusion was obtained from a much more comprehensive investigation reported by Krizek, Karadi, and Hummel (1973).

Bacteriological Analyses

Samples taken from the slurry influent, dike overflow, underlying groundwater, and a few other sources were tested before, during, and after the disposal of dredgings in the Penn 7 area to determine the presence of bacteriological organisms; the detailed results are given in Appendix E and summarized in Table 7. The standard tests for total and fecal coliform organisms were conducted by means of the membrane filter and/or the multiple tube testing techniques. The total and fecal coliform tests have been used traditionally as indicators of polluted

Table 7. Summary of Data from Bacteriological Analyses

Sample Location and Time	Total Coliforms (organisms per 100 mℓ)			Fecal Coliforms (organisms per 100 mℓ)		
	Number of Samples	Range	Mean	Number of Samples	Range	Mean
Groundwater from Wells (0 to 10 feet) August 2, 1972	2	24,000 to 32,000	28,000	2	160 to 580	370
Groundwater from Wells (10 to 20 feet) August 2, 1972	4	40 to 120,000	300[a]	4	< 1 to 5,700	< 1[b]
Groundwater from Wells (0 to 10 feet) August 1, 1973	6	100 to 55,000	19,000	6	15 to 2,400	1,270
Groundwater from Wells (10 to 20 feet) August 1, 1973	2	11,000 to 46,000	28,500	2	9,300 to 11,000	10,150
Groundwater from Wells (0 to 10 feet) August 22, 1974	3	30 to 700	260			
Groundwater from Wells (0 to 10 feet) February 6, 1975	4	0 to 700	400			
Influent Slurry August 25, 1972	5	600,000 to 2,000,000	680,000[c]	5	23,000 to 60,000	44,000
Influent Slurry August 1, 1973	3	24,000 to 165,000	24,000[d]	3	9,300 to 69,000	9,300[e]
Stagnant Mud from Disposal Area August 1, 1973	1		1,125,000	1		1,125,000
Stagnant Water from Disposal Area August 1, 1973	1		210,000	1		270
Water from Overflow Weir August 1, 1973	1		70,000	1		330
Water from Overflow Weir August 22, 1974	1		100			
Water from Maumee River August 1, 1973	1		83,000	1		1,200
Water from Maumee River August 22, 1974	1		15			
Water from Maumee River February 6, 1975	1		0			
Tap Water from C. E. Field Office August 22, 1974 and February 6, 1975	2		0			
Tap Water from Well of Local Motel August 22, 1974 and February 6, 1975	2		0			

Notes:

a Mean value excludes one sample with a value of 120,000

b Mean value excludes one sample with a value of 5,700

c Mean value excludes one sample with a value of 2,000,000

d Mean value excludes one sample with a value of 165,000

e Mean value excludes one sample with a value of 69,000

water which could be a health hazard; the presence of fecal coliforms in significant numbers suggests that fecal matter from animals or humans has contaminated the water and that other pathogenic bacteria may be present.

Although the interpretation of such tests is very difficult due to the many variables that can affect the results, the limited data given in Table 7 suggest that the slurry influent is extremely polluted from a bacteriological point of view; fecal coliforms are in the tens of thousands of organisms per 100 mℓ, and total coliforms typically range from tens of thousands to hundreds of thousands of organisms per 100 mℓ. The effluent water from the diked enclosure, as well as the water from the Maumee River, is quite polluted at some times but relatively unpolluted at other times. To place the test data in perspective, the standards for most states require zero coliforms for drinking water quality, but they allow as high as 1000 organisms per 100 mℓ for contact sports (such as swimming) and up to 5000 organisms per 100 mℓ for non-contact sports (such as boating). The state of Ohio standards for lakes and streams require that the average of at least five samples taken within 30 days does not exceed 200 fecal coliforms per 100 mℓ and that not more than 10% of the samples exceed 400 organisms per 100 mℓ. Although many more samples would have to be taken and tested before any final judgement could be made (the numbers of bacteriological organisms can change rapidly due to varying environmental conditions), it appears that the effluent water from the Penn 7 containment area resembles the general quality of the water in the Maumee River.

The situation regarding the groundwater is very difficult to assess due to the wide variation of test results. Although some localized areas appear reasonably unpolluted, others appear quite highly polluted. The

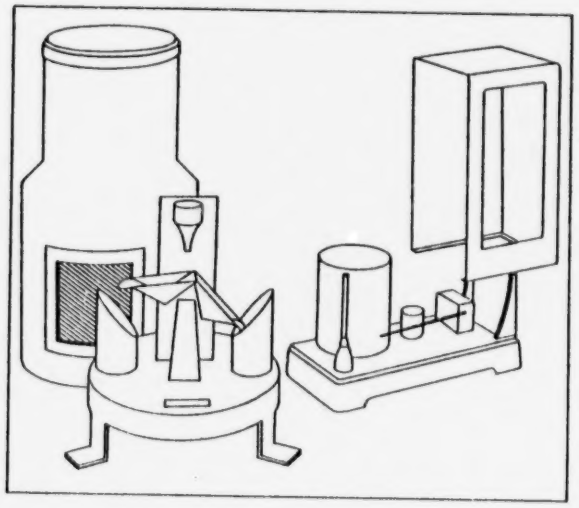
data indicate that some degree of pollution existed before any dredged spoil was placed in the diked enclosure; this was probably caused by the presence of stagnant surface waters. It was observed that many wild animals, such as pheasants, ducks, rabbits, and rats, used the partially water-filled dike enclosure as a habitat, and this could accout for the presence of coliforms in relatively high numbers. However, these data do not suggest that the disposal of dredgings in the Penn 7 area has adversely affected the quality of the groundwater from a bacteriological point of view during the time period of this study. However, the stagnant mud and water within the diked area are extremely polluted, and the groundwater may become polluted with time due to leaching of the deposited dredged materials.

WATER BUDGET

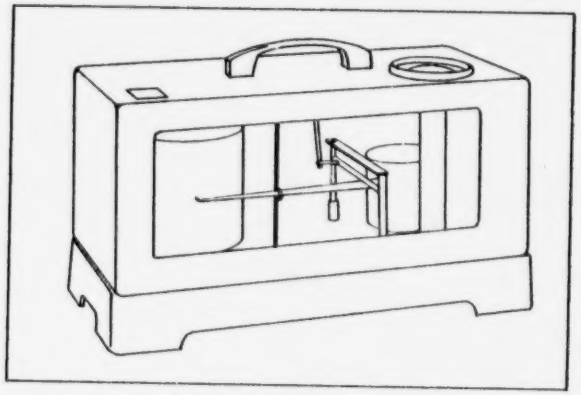
Included in this section are descriptions of the techniques and equipment (see Figures 4, 5, and 6) used to establish quantitative values for the various components of the water budget. Detailed data are presented in various appendices, and only summaries of the results are given here.

Effluent

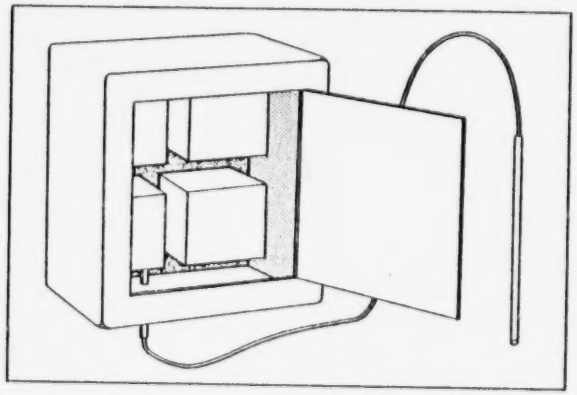
A recording flow meter (March McBirney Model 100; see Figures 4 and 5) was installed at the overflow weir to record the quantity of effluent that exited the containment area over the weir. This unit recorded the water level by means of an electronic conductivity probe and recording system, and it was able to operate unattended for 30 days. The outflow quantity was calculated from the recorded crest height in conjunction with a rectangular weir arrangement. The system was installed on October 3, 1972, before the dike had filled to the overflow level, and



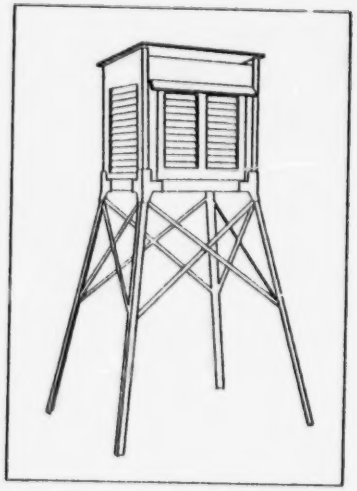
Rain Gage



Evaporimeter



Flow Meter



Weather Station

Figure 4. Schematic Diagrams of Instrumentation

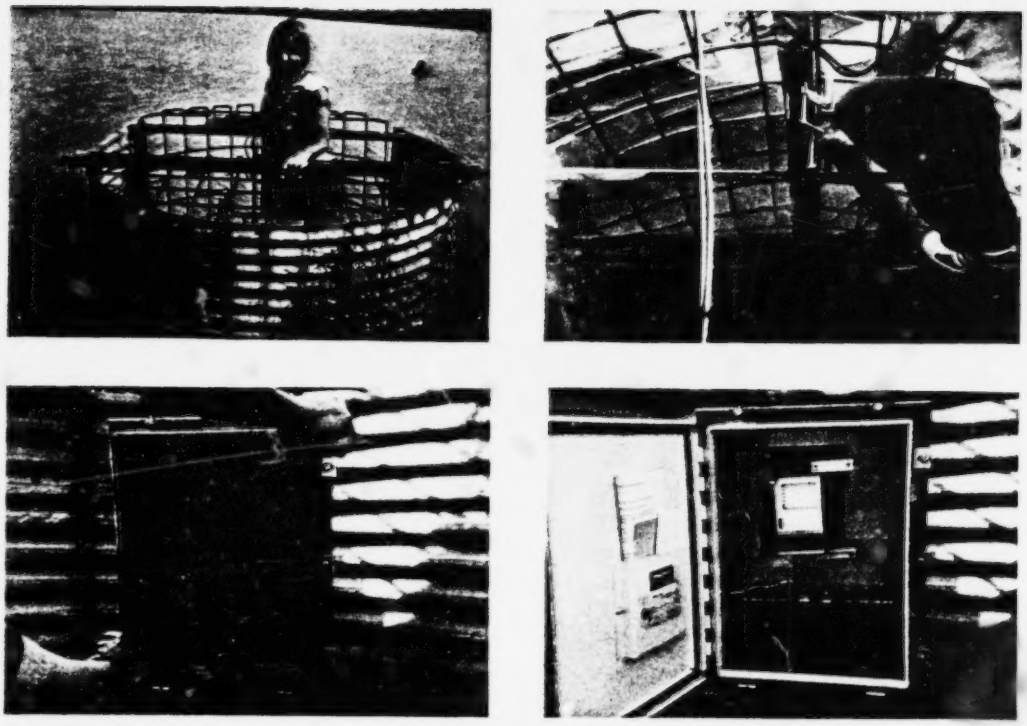


Figure 5. Photographs of Overflow Weir and Flow Meter Installation

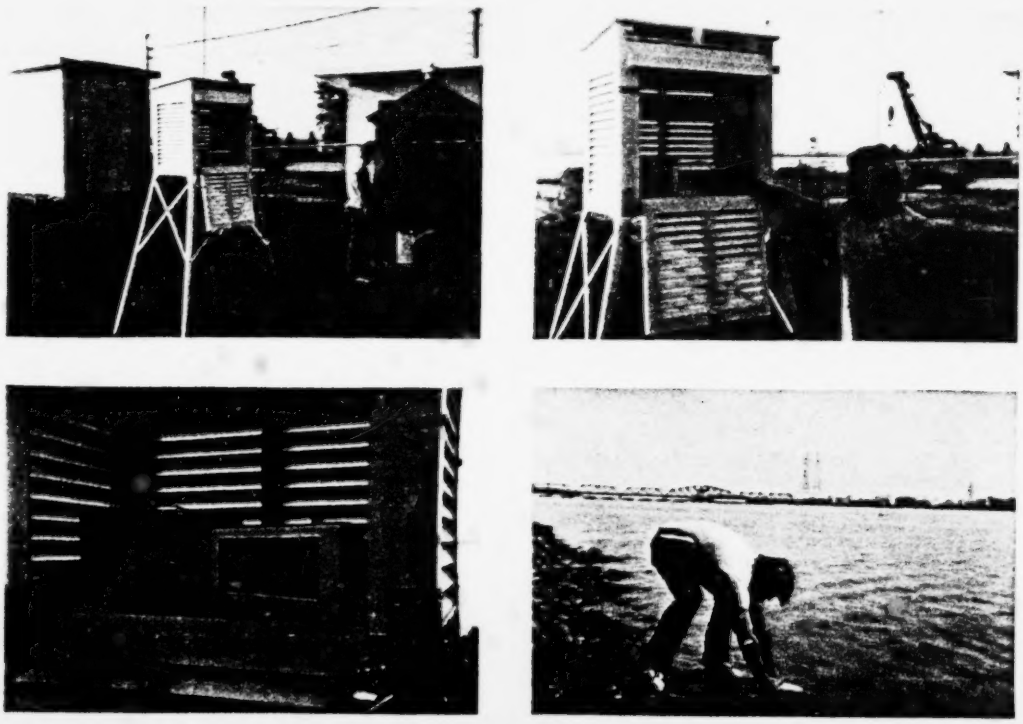


Figure 6. Photographs of Rain Gage and Evaporimeter

it began recording on October 19, 1972. The weir calibration coefficient was obtained from calibration tests described in Appendix H. The recording system operated satisfactorily for the first 24 days, but it malfunctioned during the last 30 days while the disposal area was still being filled. However, usable data obtained during the period of operation provided considerable insight into the water quantity budget. The quantity of water that left the disposal area via the overflow weir between October 19 (at which time the water first began to flow over the weir) and November 13 (at which time the probe became inoperable) was recorded, and the detailed data are given in Appendix I and summarized in Figure 7. An average of these data taken over the 26-day test period indicates that about 425,000 cubic feet (12,000 cubic meters) of water exited the disposal area each day via the overflow weir.

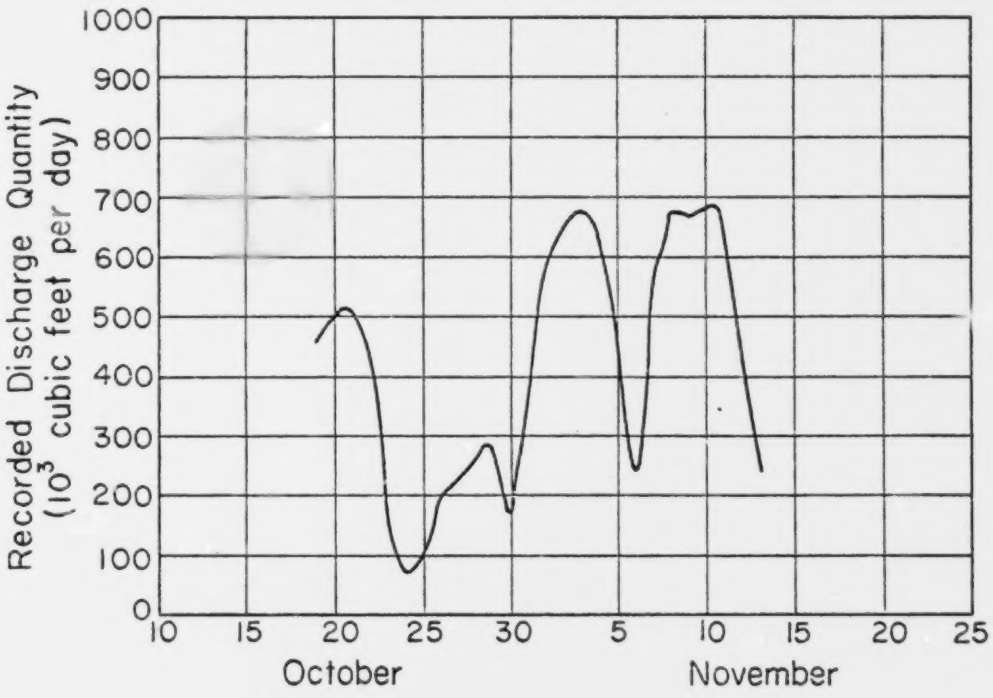


Figure 7. Quantity of Effluent versus Time

Seepage

Undetermined amounts of water may have seeped into the underlying foundation soils or through the earthen dikes during the course of this test program. Although there was no reasonable way to measure the quantity, it is believed to be small due to the low permeability of the dredged materials (Krizek and Casteleiro, 1974).

Influent

As stated previously, it was intended to obtain the quantity of influent water and slurry pumped into the disposal area from Corps of Engineers records, but available data render impossible the task of determining this quantity with any degree of accuracy. Nevertheless, the rationale presented in Appendix J indicates that inflow quantities deduced from the information available are reasonably consistent with measured outflow quantities and the nature of the pumping operation.

Precipitation and Evaporation

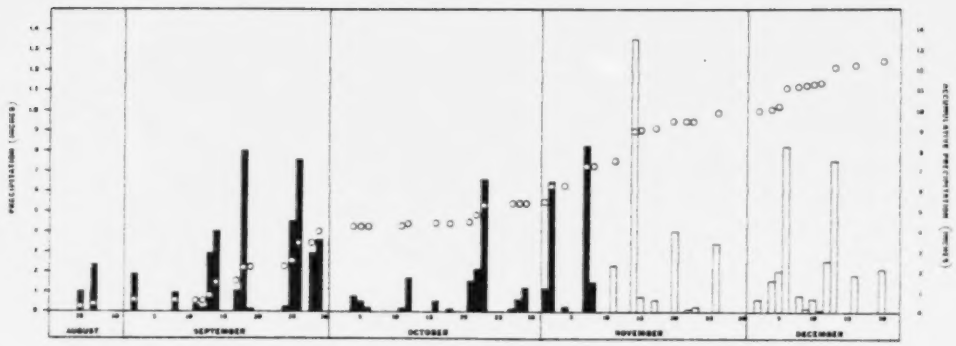
A recording rain gage (Weather Measure Model P-501; see Figures 4 and 6) and a recording evaporimeter (Weather Measure Model E-801; see Figures 4 and 6) were installed at the Toledo Field Office of the Corps of Engineers. This office is located on the bank of the Maumee River about one mile from the Penn 7 disposal area. Both recording instruments were housed in a standard U. S. Weather Bureau Shelter (Weather Measure Model IS1; see Figures 4 and 6) and recorded unattended for a seven day period. The rain measurement was performed by a "tipping bucket" mechanism, which produced a recorded mark for every 0.01 inch (0.25 millimeters) of rain collected. The evaporimeter recorded the water loss from an 8.3 square centimeter wetted filter paper that was connected to a water reservoir through a wick, and it produced a record of accumulated water evaporated over a 0 to 10 millimeter range; the

water reservoir was filled with distilled water when required, and the wetted filter paper was replaced when it became visibly dirty or discolored. No unusual maintenance was required for either instrument; chart replacement and ink pen refilling was done on a weekly basis. Both chart records were removed weekly and properly identified.

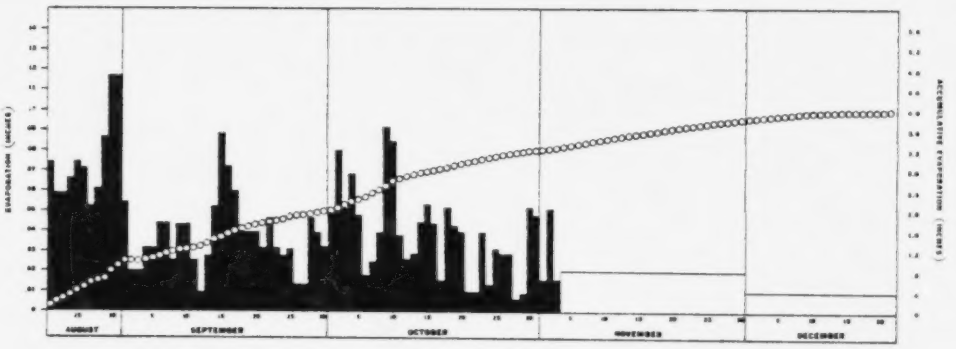
Daily records of the precipitation, evaporation, net input, and accumulative input between August 20 and December 20, 1972 are given in Appendix G, and this information is presented graphically in Figure 8. The net accumulative input over the entire test period was recorded as 8.64 inches (22.0 centimeters) which, when distributed over an area of 1.34 million square feet (0.125 million square meters), represents a total volume input to the disposal area of about 970,000 cubic feet (27,000 cubic meters) or almost 8,000 cubic feet (220 cubic meters) per day on the average. Of particular concern to this study is the 26-day period from October 19 to November 13, 1972, during which time the major part of the usable data were accumulated. Since there was a net accumulative input of 2.60 inches (6.6 centimeters) during this period, the total volume input would amount to about 290,000 cubic feet (8000 cubic meters) and the daily input was almost 11,000 cubic feet (300 cubic meters). These daily volumes represent about 2% of the daily quantity of water that exited the disposal area via the overflow weir; consequently, its role in modifying the quality of the waters comprising the water budget can be reasonably neglected.

Synthesis

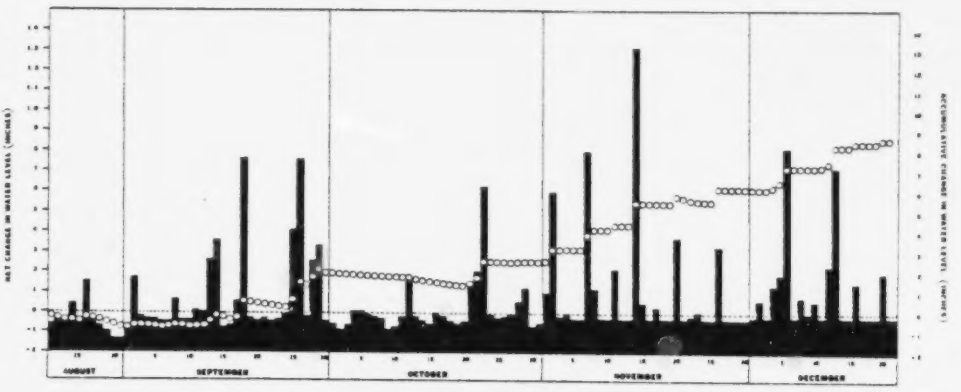
Although the water budget cannot be balanced with any degree of accuracy due to a combination of incomplete and inadequate data, the proper orders of magnitude can be reasonably well established from an



(a) Daily and Accumulated Precipitation Data



(b) Daily and Accumulated Evaporation Data



(c) Daily and Accumulated Net Change in Water Level

Figure 8. Summary of Meterological Data

overall evaluation of the available data. The quantity of effluent from the area was determined with a fair degree of confidence to average about 425,000 cubic feet (12,000 cubic meters) per day for the first 26 days during which water overflowed the weir, and the quantity of influent (Appendix J) substantiates this measurement in a general way. The weekly decreases in the recorded volume of effluent in Figure 7 are due to the fact that dredging and disposal operations ceased on Sundays.

Although not specifically measured due to a malfunction of the flow meter, U. S. Army Corps of Engineers records (Boresch, 1974) indicate that the volume of dredgings pumped into Penn 7 increased significantly after November 15, 1972, when a larger dredge (U. S. Markham) began operating. However, it is reasonable to assume that the effluent quantity increased in the same proportion to the inflow (outflow water should equal approximately 5 to 6 times the volume of solids pumped into the dike). Since the Markham pumped approximately 270,000 cubic feet 7,600 cubic meters) of solids into Penn 7 per day, as compared to about 83,000 cubic feet (2300 cubic meters) per day during the period from October 19 to November 13, 1972, approximately 1.5 million cubic feet (42,000 cubic meters) of water per day should have passed over the weir into the Maumee River.

The measured net volume of precipitation and evaporation represents less than 2% of the effluent quantity and can therefore be reasonably neglected, especially in the water quality analyses. The undetermined quantity of seepage into the underlying foundation soil is probably small due to the low permeability of both the dredgings and the upper strata of the original ground. Run-off into the containment area is almost certainly negligible due to the presence of a surrounding dike.

The total amounts of dredged material placed in Penn 7 during the 1972 and 1973 dredging seasons were about 570,000 and 350,000 cubic yards (440,000 and 270,000 cubic meters), respectively, in terms of bin-measure volume. When multiplied by 0.65 to convert bin-measure volumes to disposal-site volumes (Krizek and Giger, 1974), these materials occupy about 370,000 and 230,000 cubic yards (280,000 and 180,000 cubic meters), respectively. Assuming an in-place dry density of 50 pounds per cubic foot (8 kN/m^3) and a value of 2.70 for the specific gravity of solids, the actual solids may be determined to occupy only about 20% of the bulk volume. Hence, when viewed in context of the overall volumes of solids and water pumped into a disposal area, the net volume of the solid particles represents only a small portion of the total volume.

CONCLUSIONS

Within the scope and limitations of this four-month water quality study of the effectiveness of the Penn 7 disposal site at Toledo, Ohio, together with an associated assessment of the fate of pollutants during the dredging and disposal cycle, the following general conclusions can be advanced:

1. The concept of using a diked containment area as a settling basin to retain the solids in dredged materials does effectively improve the water quality of the mixtures that pass through it; many of the contaminants apparently associate with the solid particles, thereby settling out of suspension with the solids and reducing significantly the concentrations of polluting materials.

2. The quality of the effluent that was discharged from the disposal area is similar to that of the ambient river water and slightly better than that of the groundwater.

3. The retained spoil in the diked enclosure represents a concentrated source of various pollutants that may leach into the groundwater as time passes, thereby reducing to some extent the advantage gained by placing polluted dredged materials in confined disposal areas.

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Krizek, R. J., and Giger, M. W. (1974), "Storage Capacity of Diked Containment Areas for Polluted Dredgings," Proceedings of the Sixth World Dredging Conference, Taipei, Taiwan, pp. 353-364.

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APPENDICES

APPENDIX A

SUMMARY OF SAMPLES

Tables A-1, A-2, and A-3 and Figure A-1 give brief descriptions of the nature and locations of all A, B, and C samples that have been obtained subsequent to those listed in the report by Krizek, Karadi, and Hummel (1973). Virtually all of these samples were taken by use of techniques described by Hummel and Krizek (1974) in connection with the study reported herein, although tests were not necessarily conducted on all samples. As described in detail by Krizek, Karadi, and Hummel (1973), samples are identified by a three-part code consisting of a letter, a number, and a pair of letters. The first letter of a sample designation indicates its consistency (A samples are essentially water; B samples are water with a noticeable amount of suspended solids; C samples are slurries with approximately a 10% to 25% solids content); the number is simply a chronological number within a given consistency group; and the last pair of letters are the first letters of the city and state from which the sample was taken (TO for Toledo, Ohio in the case of these samples). When necessary, samples were iced in the field and during transportation, and they were stored in the laboratory at about 4°C until tested.

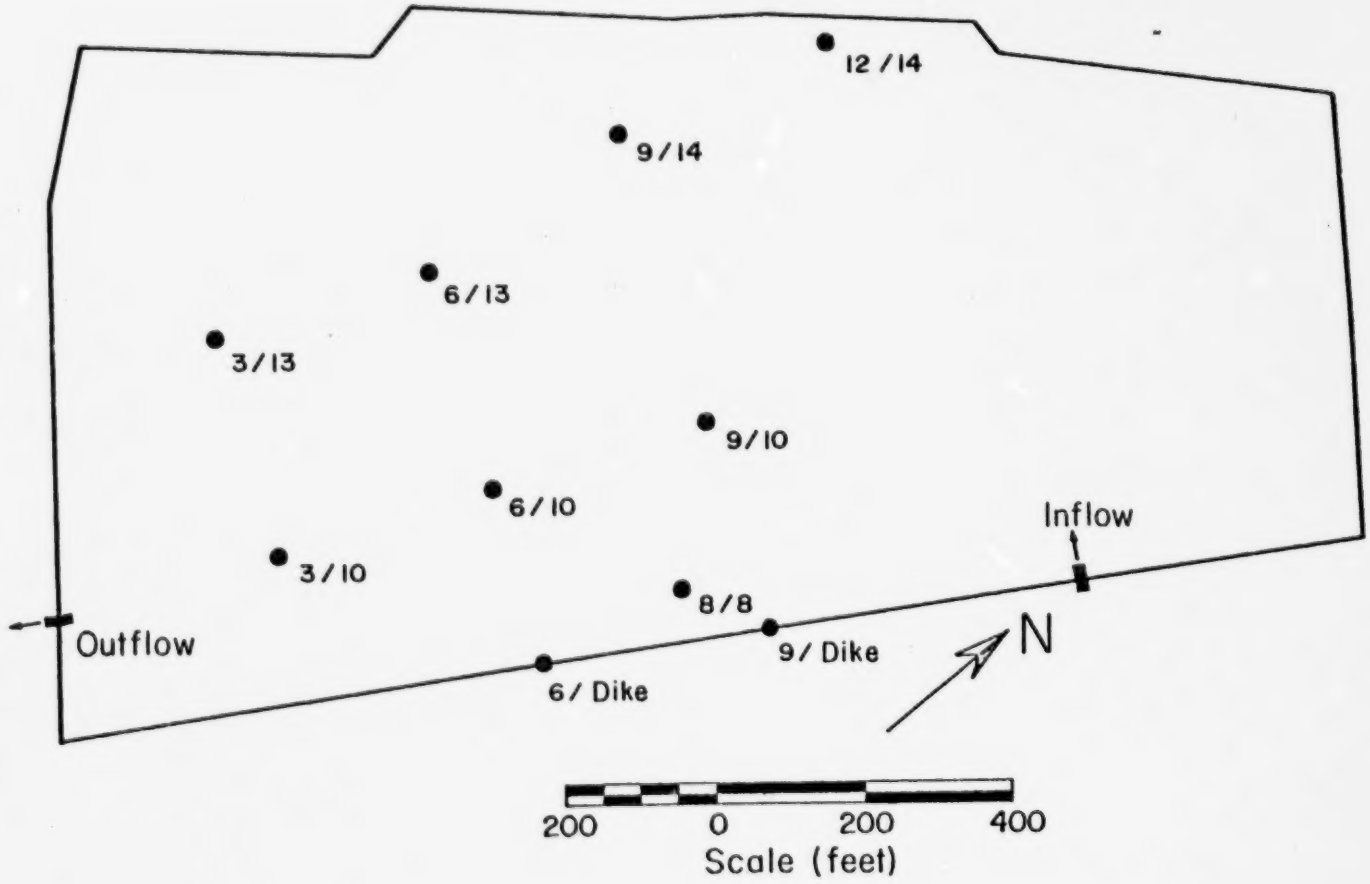


Figure A-1. Location of Wells at Penn 7 Area

Table A-1

Summary of "A" Samples

Sample Number	Date Obtained	Brief Description
A23TO	7/20/72	Water from depth of 20 feet at Penn 7 location 8/8
A24TO	7/21/72	Water from depth of 20 feet at Penn 7 location 9/10
A25TO	7/21/72	Water from depth of 10 feet at Penn 7 location 12/14
A26TO	8/ 2/72	Water from depth of 20 feet at Penn 7 location 8/8
A27TO	8/ 2/72	Water from depth of 20 feet at Penn 7 location 8/8
A28TO	8/ 2/72	Water from depth of 20 feet at Penn 7 location 6/10
A29TO	8/ 2/72	Water from depth of 20 feet at Penn 7 location 6/10
A30TO	8/ 2/72	Water from depth of 20 feet at Penn 7 location 9/10
A31TO	8/ 2/72	Water from depth of 20 feet at Penn 7 location 9/10
A32TO	8/ 3/72	Water from depth of 20 feet at Penn 7 location 9/14
A33TO	8/ 3/72	Water from depth of 20 feet at Penn 7 location 9/14
A34TO	8/ 3/72	Water from depth of 10 feet at Penn 7 location 9/14
A35TO	8/ 3/72	Water from depth of 10 feet at Penn 7 location 9/14
A36TO	8/ 3/72	Water from depth of 10 feet at Penn 7 location 12/14
A37TO	8/ 3/72	Water from depth of 10 feet at Penn 7 location 12/14
A38TO	10/ 3/72	Water from Maumee River south of Penn 7 overflow weir
A39TO	10/ 3/72	Water from Maumee River south of Penn 7 overflow weir
A40TO	10/ 3/72	Water from Penn 7 overflow weir
A41TO	10/ 3/72	Water from Penn 7 overflow weir
A42TO	10/17/72	Water from Penn 7 overflow weir
A43TO	10/17/72	Water from Penn 7 overflow weir
A44TO	10/21/72	Water from Penn 7 overflow weir
A45TO	10/21/72	Water from Penn 7 overflow weir
A46TO	10/27/72	Water from Penn 7 overflow weir
A47TO	10/30/72	Water from Penn 7 overflow weir
A48TO	11/ 1/72	Water from Penn 7 overflow weir
A49TO	11/ 3/72	Water from Penn 7 overflow weir
A50TO	11/ 9/72	Water from Penn 7 overflow weir
A51TO	11/15/72	Water from Penn 7 overflow weir
A52TO	11/15/72	Water from Penn 7 overflow weir

Table A-1 (continued)

Summary of "A" Samples

Sample Number	Date Obtained	Brief Description
A53TO	11/15/72	Water from depth of 10 feet at Penn 7 location 9/Dike
A54TO	11/15/72	Water from depth of 7 feet at Penn 7 location 9/Dike
A55TO	11/24/72	Water from Penn 7 overflow weir
A56TO	11/27/72	Water from Penn 7 overflow weir
A57TO	11/30/72	Water from Penn 7 overflow weir
A58TO	12/ 9/72	Water from Penn 7 overflow weir
A59TO	4/26/73	Water from Maumee River south of Penn 7 overflow weir
A60TO	4/26/73	Water from Maumee River south of Penn 7 overflow weir
A61TO	7/12/73	Water from 1972 well near Borehole 1 at Riverside Site
A62TO	7/12/73	Water from 1973 well near Borehole 1 at Riverside Site
A63TO	7/12/73	Water from 1973 well near Borehole 6 at Riverside Site
A64TO	7/12/73	Water from depth of 20 feet at Penn 7 location 9/14
A65TO	7/12/73	Water from depth of 10 feet at Penn 7 location 9/14
A66TO	7/12/73	Water from depth of 8 feet at Penn 7 location 6/13
A67TO	7/12/73	Water from depth of 10 feet at Penn 7 location 6/10
A68TO	7/12/73	Water from depth of 20 feet at Penn 7 location 6/10
A69TO	7/12/73	Water from depth of 8 feet at Penn 7 location 6/Dike
A70TO	7/12/73	Water from depth of 8 feet at Penn 7 location 9/Dike
A71TO	7/12/73	Water from Maumee River south of Penn 7 overflow weir
A72TO	7/12/73	Water from Penn 7 overflow weir
A73TO	8/ 1/73	Water from depth of 10 feet at Penn 7 location 6/10
A74TO	8/ 1/73	Water from depth of 20 feet at Penn 7 location 6/10
A75TO	8/ 1/73	Water from depth of 8 feet at Penn 7 location 6/13
A76TO	8/ 1/73	Water from depth of 10 feet at Penn 7 location 9/14
A77TO	8/ 1/73	Water from depth of 20 feet at Penn 7 location 9/14
A78TO	8/ 1/73	Water from depth of 8 feet at Penn 7 location 6/Dike
A79TO	8/ 1/73	Water from depth of 8 feet at Penn 7 location 9/Dike
A80TO	8/ 1/73	Water from Maumee River near Penn 7
A81TO	8/ 1/73	Water from Penn 7 overflow weir
A82TO	8/ 1/73	Stagnant water from inside Penn 7

Table A-1 (continued)

Summary of "A" Samples

Sample Number	Date Obtained	Brief Description
A83TO	8/22/74	Tap water from U.S. Army Corps of Engineers Toledo Field Office
A84TO	8/22/74	Tap water from well of Continental Motel near Toledo
A85TO	8/22/74	Water from Maumee River near Penn 7
A86TO	8/22/74	Water from depth of 9 feet at Penn 7 location 6/10
A87TO	8/22/74	Water from depth of 11 feet at Penn 7 location 6/10
A88TO	8/22/74	Water from depth of 7 feet at Penn 7 location 6/Dike
A89TO	8/22/74	Water from bottom of Penn 7 overflow weir
A90TO	2/ 6/75	Tap water from U.S. Army Corps of Engineers Toledo Field Office
A91TO	2/ 6/75	Tap water from well of Continental Motel near Toledo
A92TO	2/ 6/75	Water from Maumee River near Penn 7
A93TO	2/ 6/75	Water from depth of 4 feet at Penn 7 location 6/10
A94TO	2/ 6/75	Water from depth of 10 feet at Penn 7 location 6/10
A95TO	2/ 6/75	Water from depth of 4 feet at Penn 7 location 9/14
A96TO	2/ 6/75	Water from depth of 10 feet at Penn 7 location 9/14

Table A-2

Summary of "B" Samples

Sample Number	Date Obtained	Brief Description
B10TO	12/ 5/72	Material taken from hopper overflow at beginning of dredging operation
B11TO	12/ 5/72	Material taken from hopper overflow after 10 minutes of dredging
B12TO	12/ 5/72	Material taken from hopper overflow at end of dredging operation
B13TO	12/14/72	Water from Penn 7 overflow weir

Table A-3

Summary of "C" Samples

Sample Number	Date Obtained	Sampling Time	Source & Location
C29TO	8/25/72	9:15 25	Material from discharge pipe at Penn 7
C30TO	8/25/72	9:15 25	Material from discharge pipe at Penn 7
C31TO	8/25/72	11:45 5	Material from discharge pipe at Penn 7
C32TO	8/25/72	11:45 5	Material from discharge pipe at Penn 7
C33TO	8/25/72	11:55 15	Material from discharge pipe at Penn 7
C34TO	8/25/72	11:55 15	Material from discharge pipe at Penn 7
C35TO	8/25/72	14:00 5	Material from discharge pipe at Penn 7
C36TO	8/25/72	14:00 5	Material from discharge pipe at Penn 7
C37TO	8/25/72	14:10 15	Material from discharge pipe at Penn 7
C38TO	8/25/72	14:10 15	Material from discharge pipe at Penn 7
C39TO	10/17/72	9:15 10	Material from discharge pipe at Penn 7
C40TO	10/17/72	14:15 10	Material from discharge pipe at Penn 7
C41TO	10/17/72	19:15 10	Material from discharge pipe at Penn 7
C42TO	10/18/72	7:30 10	Material from discharge pipe at Penn 7
C43TO	10/18/72	13:15 5	Material from discharge pipe at Penn 7
C44TO	10/18/72	13:20 10	Material from discharge pipe at Penn 7
C45TO	10/18/72	13:25 15	Material from discharge pipe at Penn 7
C46TO	10/18/72	13:30 20	Material from discharge pipe at Penn 7
C47TO	10/18/72	13:35 25	Material from discharge pipe at Penn 7
C48TO	10/18/72	18:30 10	Material from discharge pipe at Penn 7
C49TO	10/19/72	11:30 10	Material from discharge pipe at Penn 7
C50TO	10/19/72	14:30 10	Material from discharge pipe at Penn 7
C51TO	10/19/72	17:30 10	Material from discharge pipe at Penn 7
C52TO	10/20/72	7:45 10	Material from discharge pipe at Penn 7
C53TO	10/20/72	14:20 5	Material from discharge pipe at Penn 7
C54TO	10/20/72	14:25 10	Material from discharge pipe at Penn 7
C55TO	10/20/72	14:30 15	Material from discharge pipe at Penn 7
C56TO	10/20/72	14:35 20	Material from discharge pipe at Penn 7
C57TO	10/20/72	14:40 25	Material from discharge pipe at Penn 7
C58TO	10/20/72	17:30 10	Material from discharge pipe at Penn 7

Table A-3 (continued)

Summary of "C" Samples

Sample Number	Date Obtained	Sampling Time	Source & Location
C59TO	10/21/72	7:30 10	Material from discharge pipe at Penn 7
C60TO	10/21/72	10:00 10	Material from discharge pipe at Penn 7
C61TO	10/21/72	13:15 5	Material from discharge pipe at Penn 7
C62TO	10/21/72	13:20 10	Material from discharge pipe at Penn 7
C63TO	10/21/72	13:25 15	Material from discharge pipe at Penn 7
C64TO	10/21/72	17:15 5	Material from discharge pipe at Penn 7
C65TO	10/21/72	17:20 10	Material from discharge pipe at Penn 7
C66TO	10/21/72	17:25 15	Material from discharge pipe at Penn 7
C67TO	10/21/72	17:30 20	Material from discharge pipe at Penn 7
C68TO	10/21/72	17:35 25	Material from discharge pipe at Penn 7
C69TO	10/21/72	20:30 5	Material from discharge pipe at Penn 7
C70TO	10/21/72	20:35 10	Material from discharge pipe at Penn 7
C71TO	10/21/72	20:40 15	Material from discharge pipe at Penn 7
C72TO	10/27/72	10:30 10	Material from discharge pipe at Penn 7
C73TO	10/30/72	15:30 End	Material from discharge pipe at Penn 7
C74TO	11/ 1/72	19:00 10	Material from discharge pipe at Penn 7
C75TO	11/ 3/72	15:30 10	Material from discharge pipe at Penn 7
C76TO	11/ 9/72	17:30 End	Material from discharge pipe at Penn 7
C77TO	11/24/72	17:00 10	Material from discharge pipe at Penn 7
C78TO	11/27/72	17:00 10	Material from discharge pipe at Penn 7
C79TO	11/30/72	12:30 10	Material from discharge pipe at Penn 7
C80TO	12/ 4/72	15:00 3	Material from discharge pipe at Penn 7
C81TO	12/ 5/72	11:00	Bottom sediments taken from tug boat by Ekman Dredge from lake bottom about one mile northeast of Island
C82TO	12/ 5/72	11:10	Bottom sediments taken from tug boat by Ekman Dredge from lake bottom about one mile northeast of Island
C83TO	12/ 5/72	11:20	Bottom sediments taken from tug boat by Ekman Dredge from lake bottom about one mile northeast of Island
C84TO	12/ 5/72	12:30	Material taken by Ekman Dredge from dredge hopper at approximately one-third load

Table A-3 (continued)

Summary of "C" Samples

Sample Number	Date Obtained	Sampling Time		Source & Location
C85TO	12/ 5/72	12:40		Material taken by Ekman Dredge from dredge hopper at approximately two-thirds load
C86TO	12/ 5/72	12:50		Material taken by Ekman Dredge from dredge hopper at approximately full load
C87TO	12/ 5/72	13:30	3	Material from discharge pipe at Penn 7
C88TO	12/ 5/72	13:30	3	Material from discharge pipe at Penn 7
C89TO	12/ 5/72	13:30	3	Material from discharge pipe at Penn 7
C90TO	12/ 5/72	13:34	7	Material from discharge pipe at Penn 7
C91TO	12/ 5/72	13:34	7	Material from discharge pipe at Penn 7
C92TO	12/ 5/72	13:34	7	Material from discharge Pipe at Penn 7
C93TO	12/ 5/72	13:38	11	Material from discharge pipe at Penn 7
C94TO	12/ 5/72	13:38	11	Material from discharge pipe at Penn 7
C95TO	12/ 5/72	13:38	11	Material from discharge pipe at Penn 7
C96TO	12/ 5/72	13:42	15	Material from discharge pipe at Penn 7
C97TO	12/ 5/72	13:42	15	Material from discharge pipe at Penn 7
C98TO	12/ 5/72	13:42	15	Material from discharge pipe at Penn 7
C99TO	12/ 5/72	14:45	18	Material from discharge pipe at Penn 7
C100TO	12/ 5/72	13:45	18	Material from discharge pipe at Penn 7
C101TO	12/ 5/72	13:45	18	Material from discharge pipe at Penn 7
C102TO	12/ 6/72	17:35	5	Material from discharge pipe at Penn 7
C103TO	12/ 6/72	17:45	15	Material from discharge pipe at Penn 7
C104TO	12/ 7/72	17:10	5	Material from discharge pipe at Penn 7
C105TO	12/ 7/72	17:20	15	Material from discharge pipe at Penn 7
C106TO	12/ 9/72	18:00	5	Material from discharge pipe at Penn 7
C107TO	12/ 9/72	18:10	10	Material from discharge pipe at Penn 7
C108TO	12/12/72	17:35	5	Material from discharge pipe at Penn 7
C109TO	12/12/72	17:45	15	Material from discharge pipe at Penn 7
C110TO	12/13/72	7:50	5	Material from discharge pipe at Penn 7
C111TO	12/13/72	8:00	15	Material from discharge pipe at Penn 7

Table A-3 (continued)

Summary of "C" Samples

Sample Number	Date Obtained	Sampling Time	Source & Location
C112TO	12/14/72	17:10 5	Material from discharge pipe at Penn 7
C113TO	12/14/72	17:20 10	Material from discharge pipe at Penn 7
C114TO	12/15/72	7:42 5	Material from discharge pipe at Penn 7
C115TO	12/15/72	7:52 15	Material from discharge pipe at Penn 7
C116TO	8/ 1/73	Load 1	Material from discharge pipe at Penn 7
C117TO	8/ 1/73	Load 2	Material from discharge pipe at Penn 7
C118TO	8/ 1/73	Load 3	Material from discharge pipe at Penn 7
C119TO	8/ 1/73		Stagnant mud from inside Penn 7
C120TO	8/ 1/73		Material from discharge pipe at Penn 7
C121TO	8/16/73		Material from inside Penn 7

APPENDIX B

METHODS OF CHEMICAL ANALYSES

The testing procedures used to conduct most of the chemical analyses reported in this study are generally the same as those described in the Thirteenth Edition (1971) of Standard Methods for the Examination of Water and Wastewater. An outline of the overall method of analysis is illustrated in Figure B-1.

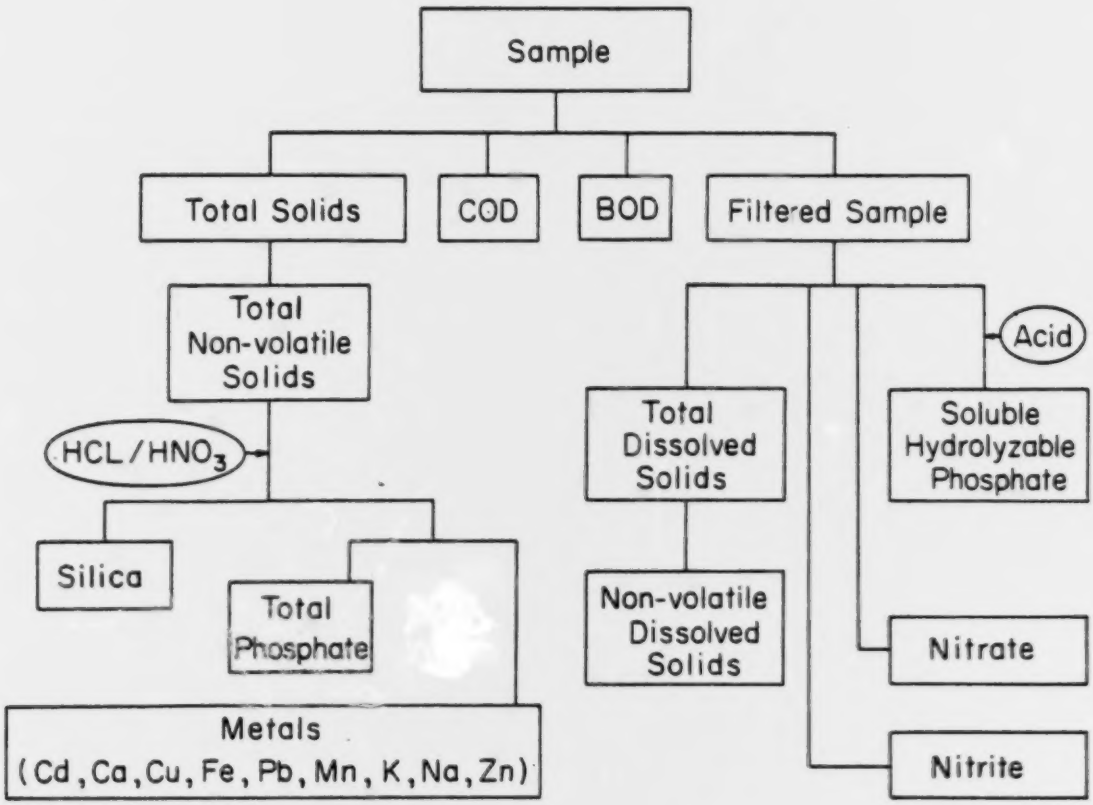


Figure B-1. Outline of Test Program

TOTAL SOLIDS

After thoroughly mixing the total sample, a portion was poured into a preweighed crucible with a capacity of 20 or 40 ml. In the case of the C samples, it was found convenient to use a sawed-off pipette to extract the sample from the container; the pipette simultaneously served as a stirrer while the sample was withdrawn. The crucible with the sample was weighed, put into an oven at 105°C, and dried for several hours. After the sample was dry, the hot crucible containing the dried sample was placed in a dessicator containing calcium chloride, allowed to reach room temperature, and weighed. The percent Total Solids was determined as

$$\text{Total Solids (\%)} = \frac{W_{DS} - W_C}{W_S - W_C} \times 100,$$

where W_C is the weight of the crucible, W_S is the weight of the crucible with the sample before drying, and W_{DS} is the weight of the crucible with the sample after drying.

TOTAL NONVOLATILE SOLIDS AND TOTAL VOLATILE SOLIDS

The dried sample from the total solids determination was ignited in a muffle furnace at 600°C for approximately two hours, placed in a dessicator, and allowed to cool to room temperature, after which it was weighed. The percent Total Nonvolatile Solids was determined as

$$\text{Total Nonvolatile Solids (\%)} = \frac{W_{IS} - W_C}{W_S - W_C} \times 100,$$

where W_C is the weight of the crucible, W_S is the weight of the crucible with the sample before drying, and W_{IS} is the weight of the crucible with the sample after ignition. The Total Volatile Solids is simply

Total Volatile Solids (%) = Total Solids (%) - Total Nonvolatile Solids (%).

NONVOLATILE AND VOLATILE SUSPENDED AND DISSOLVED SOLIDS

The solids content of a sample can be diagrammatically represented as shown in Figure B-2. By measuring the total solids, total volatile solids, total dissolved solids, and volatile suspended solids on two different samples (one a filtered sample), all of the parameters depicted in Figure B-2 can be determined. With the use of the flow diagram shown in Figure B-3 (where the quantities indicated by an asterisk were measured) and the following terminology:

W_{S1} = weight of sample 1

W_{S2} = weight of sample 2

W_{TS} = weight of total solids

W_W = weight of water

W_{TVS} = weight of total volatile solids

W_{TNS} = weight of total nonvolatile solids

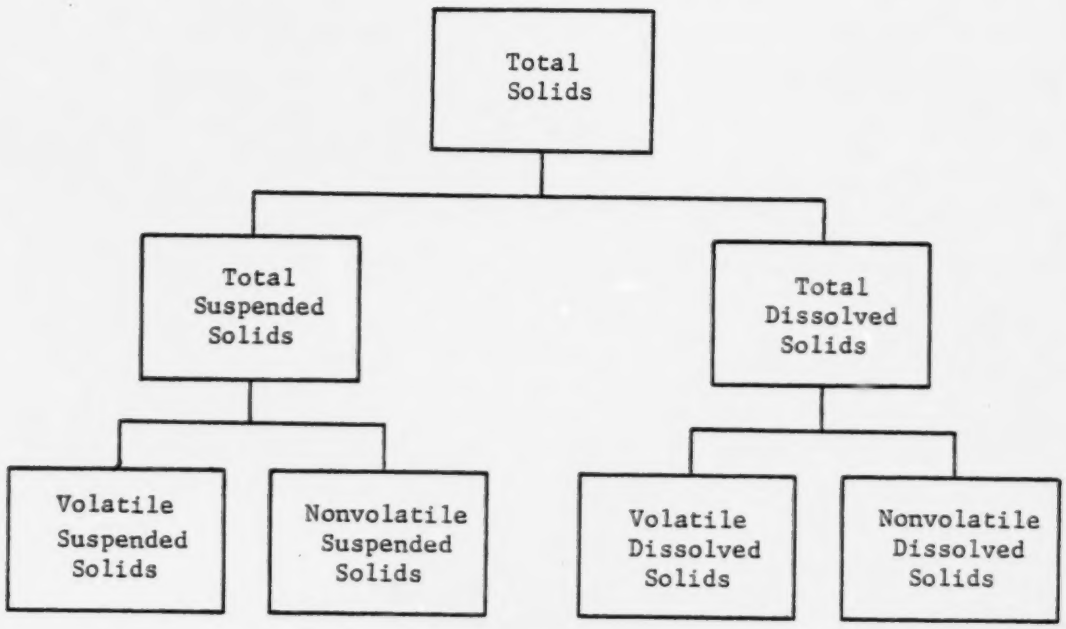
W_{DSS} = weight of dissolved solids sample

W_{TSS} = weight of total suspended solids

W_{TDS} = weight of total dissolved solids

W_{VDS} = weight of volatile dissolved solids

W_{NDS} = weight of nonvolatile dissolved solids



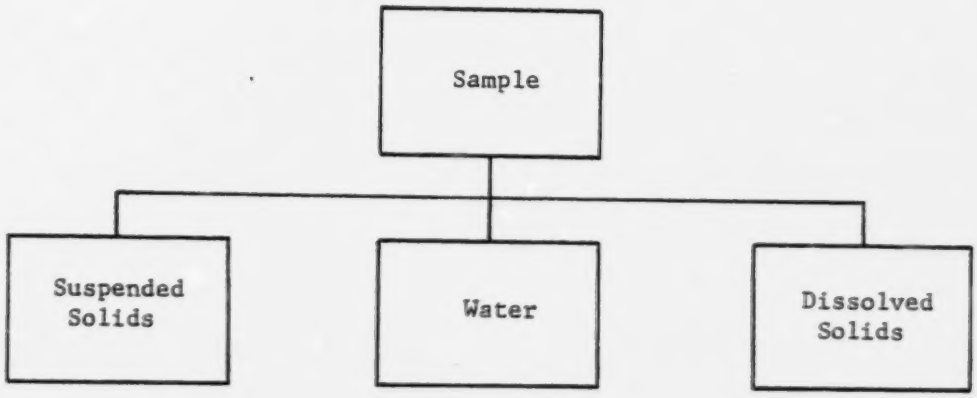


Figure B-2. Characterization of Solids in a Typical Sample

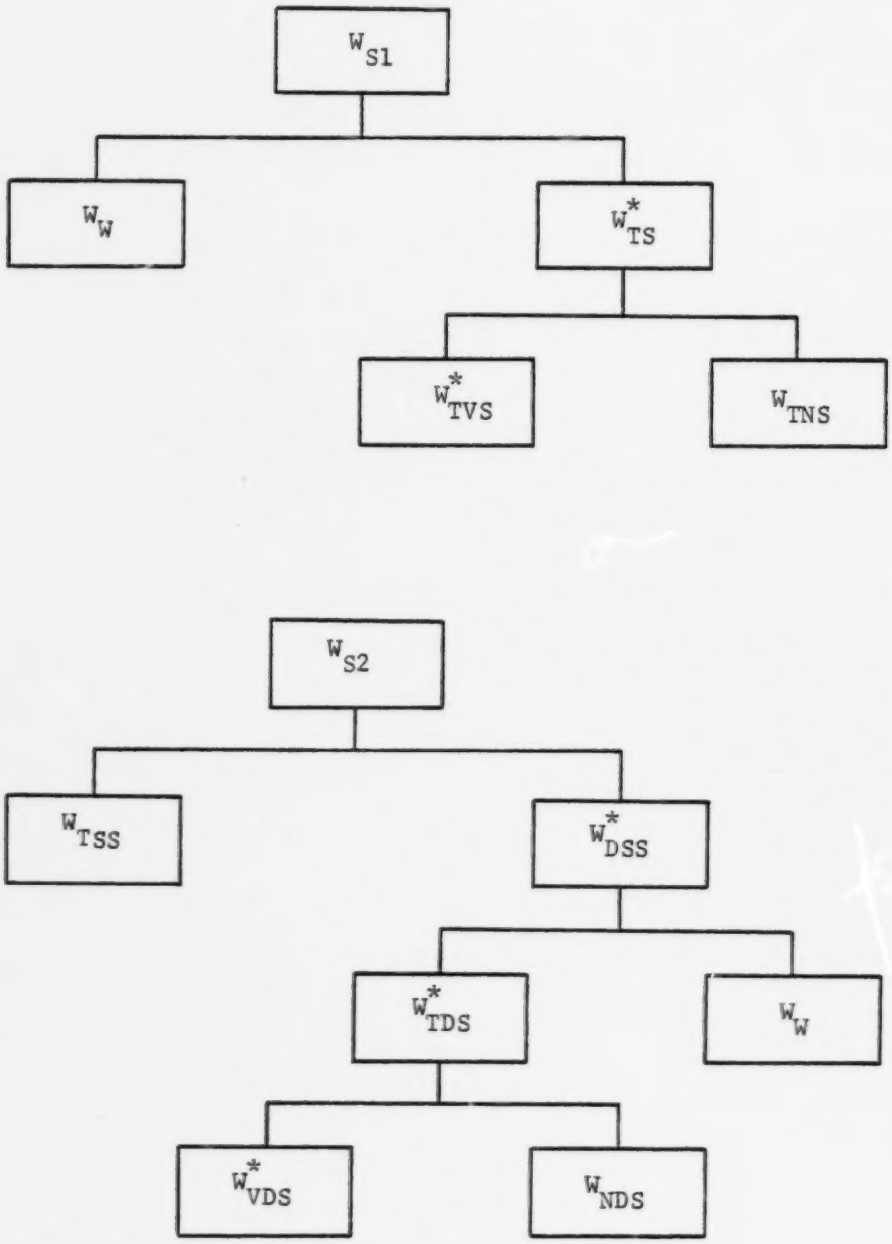


Figure B-3. Outline of Test Procedure for Solids Content Determinations

the indicated parameters can be expressed in terms of the following relationships:

$$\text{Total Solids (\%)} = \frac{W_{TS}}{W_{S1}} \times 100$$

$$\text{Volatile Dissolved Solids (\%)} = \frac{R\, W_{VDS}}{W_{S1}} \times 100$$

$$\text{Nonvolatile Dissolved Solids (\%)} = \frac{R(W_{TDS} - W_{VDS})}{W_{S1}} \times 100$$

$$\text{Volatile Suspended Solids (\%)} = \frac{W_{TVS} - R\, W_{VDS}}{W_{S1}} \times 100$$

$$\text{Nonvolatile Suspended Solids (\%)} = \frac{W_{TS} - W_{TVS} - R(W_{TDS} - W_{VDS})}{W_{S1}} \times 100$$

where $R = \frac{W_{S1} - W_{TS}}{W_{DSS} - W_{TDS}}$.

CHEMICAL OXYGEN DEMAND

The procedure used to determine the chemical oxygen demand (COD) was basically the same as that described in the Thirteenth Edition of Standard Methods. A small spatula of mercuric sulfate was added to a measured sample in a 300 ml flask; then, sufficient 0.25N potassium dichromate solution was added to oxidize all the material and concentrated sulfuric acid containing silver sulfate was added in small increments with cooling. The solution was refluxed for two hours, cooled, diluted with deionized water, and titrated (using ferroin indicator) with ferrous ammonium sulfate solution that had been standardized the same day with standard potassium dichromate solution. For the A samples a 20 ml or 25 ml sample was used, and 10 ml of 0.25N potassium dichromate and 30 ml of sulfuric acid containing silver sulfate were added.

Because of the variability of the COD for the B and C samples, initial runs with 1, 2, 4, and 8 milliliters of sample were made to determine the approximate value of the COD. Then, a second run was made to obtain the actual COD. Because of the relatively high COD for these samples, typically 25 ml of 0.25N potassium dichromate and 60 ml of sulfuric acid containing silver sulfate were added. Also, in these cases, it was difficult to obtain a small sample that was representative of the total sample, because the solid particles in the sample tended to settle before a representative sample could be taken. It was found that a fairly representative sample could be obtained by vigorously shaking the container and stirring the total sample with a sawed-off pipette while simultaneously extracting the sample to be tested with the pipette.

BIOCHEMICAL OXYGEN DEMAND

The procedure used to determine the biochemical (or biological) oxygen demand (BOD) was the same as that described in the Thirteenth Edition of Standard Methods.

SILICA

Silica was determined by heating a weighed sample in a crucible in an oven at 105°C to remove the water and at 600°C to remove the volatile components. The nonvolatile material that remained was digested on a steam bath for two hours with a mixture of hydrochloric acid and nitric acid (10:1). After cooling, the mixture was filtered into a preweighed gooch crucible fitted with a glass fiber filter. The silica was washed several times with deionized water, dried at 105°C in an oven, cooled in a dessicator containing calcium chloride, and weighed. The percent silicon, expressed as silicon dioxide or silica, can be calculated as

$$\text{Silica (\%)} = \frac{W_{CS} - W_C}{W_S} \times 100$$

where W_C is the weight of the crucible, W_{CS} is the weight of the crucible with the silica, and W_S is the weight of the sample.

TOTAL PHOSPHATE AND SOLUBLE HYDROLYZABLE PHOSPHATE

The filtrate from the silica determination, together with the washings, was put into a 100 ml volumetric flask and brought to value with deionized water for the determination of total phosphate. A filtered sample treated with "strong acid" (Method 223B, Preliminary Acid Hydrolysis Step for Condensed Phosphates, from the Thirteenth Edition of Standard Methods) was used to determine the soluble hydrolyzable phosphate. The 223E Stannous Chloride Method was used for the actual determination of the phosphate content. The extraction procedure (paragraph 4d) was employed to eliminate interferences from high concentrations of iron.

NITRATE AND NITRITE

A Hach Model DR-EL was used to determine nitrate and nitrite. The nitrate determination is a cadmium reduction method diazotized with 1-naphthylamine sulfanilic acid. The nitrite determination is a diazotization method with 1-naphthylamine sulfanilic acid. Standard sodium nitrate and sodium nitrite were used for calibration.

METALS

The following metals were determined by atomic absorption spectroscopy with a Jarrell-Ash Atomic Absorption Spectrophotometer (Model 82-500):

Metal	Line Å	Method
Cadmium	2288	Atomic Absorption
Calcium	4227	Atomic Absorption
Copper	3247	Atomic Absorption
Iron	2483	Atomic Absorption
Lead	2170	Atomic Absorption
Manganese	2795	Atomic Absorption
Potassium	7665	Emission
Sodium	5890	Emission
Zinc	2139	Atomic Absorption

The sample used to determine the metals was the same as the one used to determine the total phosphate, and it was obtained from digestion of the nonvolatile solids with acid.

APPENDIX C

RESULTS OF CHEMICAL ANALYSES ON INFLUENT-EFFLUENT SAMPLES

The results of an extensive series of chemical analyses on water and slurry samples are summarized in Tables C-1, C-2, and C-3. These tests were conducted in the laboratories at Northwestern University by Dr. Leo A. Raphaelian using the techniques described in Appendix B. The source and nature of all samples are given in Appendix A.

Table C-1

Chemical Analyses on "A" Samples

Chemical Parameter	Units	A26TO	A28TO	A30TO	A32TO	A34TO	A36TO
Total Solids	%	0.116	0.120	0.147	0.381	0.294	0.451
Total Nonvolatile Solids	%	0.060	0.070	0.075	0.285	0.206	0.342
Total Volatile Solids	%	0.056	0.051	0.072	0.096	0.088	0.110
Nonvolatile Suspended Solids	%	0.034	0.040	0.024	0.189	0.133	0.278
Volatile Suspended Solids	%	0.023	0.003	0.043	0.056	0.037	0.062
Nonvolatile Dissolved Solids	%	0.026	0.030	0.051	0.096	0.073	0.064
Volatile Dissolved Solids	%	0.033	0.048	0.029	0.040	0.051	0.048
Total Silica	%	0.041	0.040	0.045	0.137	0.064	0.176
Chemical Oxygen Demand	mg/l	114	91	118	254	301	297
Biochemical Oxygen Demand	mg/l	8	<1	<1	13	6	1
Total Nitrogen	ppm	22	15	17	6	19	2
Ammonia Nitrogen	ppm	22	15	17	6	19	2
Nitrite Nitrogen	ppm	<0.01	<0.01	<0.01	0.05	0.07	0.025
Nitrate Nitrogen	ppm	12.5	14.9	12.3	7.3	6.4	9.2
Total Phosphate	ppm	5.3			5.0	3.8	6.5
Soluble Phosphate	ppm						
Cadmium	ppm	<0.34	<0.36	<0.44	<0.37	<0.33	<0.45
Calcium	ppm	165	209	236	453	332	519
Copper	ppm	<7	<7	<9	<7	<7	<9
Iron	ppm	57	43	58	85	62	103
Lead	ppm	<7	<7	<9	<7	<7	<9
Manganese	ppm	3.4	3.6	<4.4	<3.7	<3.3	4.5
Potassium	ppm	6.9	7.2	8.7	47.5	73.1	44.7
Sodium	ppm	8.9	18.0	19.6	59.4	128.3	47.4
Zinc	ppm	0.7	0.8	<0.9	1.2	1.2	1.7
Oil and Grease	%						
pH							

Table C-1 (continued)

Chemical Analyses on "A" Samples

Chemical Parameter	Units	A38TO	A40TO	A42TO	A43TO	A44TO	A45TO
Total Solids	%	0.023	0.029	0.035	0.034	0.033	0.038
Total Nonvolatile Solids	%		0.022	0.015	0.024	0.020	0.013
Total Volatile Solids	%		0.007	0.020	0.010	0.013	0.025
Nonvolatile Suspended Solids	%	0.019					
Volatile Suspended Solids	%	0.004					
Nonvolatile Dissolved Solids	%						
Volatile Dissolved Solids	%						
Total Silica	%	0.012	0.021	0.012	0.017	0.017	0.031
Chemical Oxygen Demand	mg/l	123	123	102	94	215	127
Biochemical Oxygen Demand	mg/l	2	18	11	12	11	9
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate Nitrogen	ppm	7.8	5.0	9.4	12.3	4.2	9.9
Total Phosphate	ppm	3.9	6.5	6.1	5.7	4.1	7.0
Soluble Phosphate	ppm						
Cadmium	ppm	<0.30	<0.34	<0.34	<0.34	<0.32	<0.29
Calcium	ppm	75	75	111	118	100	94
Copper	ppm	7,5	<7	<6	<7	<6	5.7
Iron	ppm	10	<6	11	<6	7	8
Lead	ppm	<6	<7	<6	<7	<6	11.4
Manganese	ppm	<3.0	<3.4	<3.2	<3.4	<3.2	<2.9
Potassium	ppm	9.9	9.2	12.7	12.3	12.9	11.4
Sodium	ppm	10.2	25.1	27.6	26.9	23.9	22.8
Zinc	ppm	0.8	0.7	<0.6	0.7	<0.6	0.7
Oil and Grease	%						
pH		6.8	6.9	6.9	6.9	6.9	6.9

Table C-1 (continued)

Chemical Analyses on "A" Samples

Chemical Parameter	Units	A46TO	A47TO	A48TO	A49TO	A50TO	A51TO
Total Solids	%	0.053	0.056	0.055	0.058	0.053	0.053
Total Nonvolatile Solids	%	0.044	0.043	0.046	0.046	0.039	0.038
Total Volatile Solids	%	0.009	0.013	0.009	0.012	0.014	0.015
Nonvolatile Suspended Solids	%						
Volatile Suspended Solids	%						
Nonvolatile Dissolved Solids	%						
Volatile Dissolved Solids	%						
Total Silica	%		0.010	0.013	0.002	0.002	0.001
Chemical Oxygen Demand	mg/l	97	70	103	93	160	120
Biochemical Oxygen Demand	mg/l	1	1	1	2		1
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate Nitrogen	ppm	8.5	9.3	7.2	8.4	4.3	
Total Phosphate	ppm	3.1	3.3	2.4	4.3		3.7
Soluble Phosphate	ppm						
Cadmium	ppm	<0.20	<0.20	<0.20	<0.20	<0.21	<0.20
Calcium	ppm	92	99	100	94	93	82
Copper	ppm	<2.6	2.5	2.5	2.5	4.1	2.6
Iron	ppm	2.6	5.1	2.5	2.5	5.1	2.6
Lead	ppm	<5.1	<5.1	<5.0	<5.1	<5.2	<5.1
Manganese	ppm	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Potassium	ppm	6.4	7.6	4.0	4.9	4.1	2.4
Sodium	ppm	19.4	22.9	16.5	12.0	8.5	8.2
Zinc	ppm	<0.5	1.0	0.5	0.5	0.7	0.5
Oil and Grease	%						
pH		6.7	6.7	6.6	6.7	6.3	6.9

Table C-1 (continued)

Chemical Analyses on "A" Samples

Chemical Parameter	Units	A52TO	A53TO	A54TO	A55TO	A56TO	A57TO
Total Solids	%	0.053	0.079	0.233	0.043	0.046	0.054
Total Nonvolatile Solids	%	0.040			0.039	0.039	0.045
Total Volatile Solids	%	0.013			0.011	0.007	0.010
Nonvolatile Suspended Solids	%		0.066	0.211			
Volatile Suspended Solids	%		0.013	0.022			
Nonvolatile Dissolved Solids	%						
Volatile Dissolved Solids	%						
Total Silica	%	0.004	0.001	0.127	0.027	0.042	0.002
Chemical Oxygen Demand	mg/l	180	156	2	126	173	230
Biochemical Oxygen Demand	mg/l	2	166	1	3	4	1
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.015		<0.01	<0.01	<0.01	<0.01
Nitrate Nitrogen	ppm	6.6		15.3	10.6	11.7	5.0
Total Phosphate	ppm	3.2		16.3	4.4		4.1
Soluble Phosphate	ppm						
Cadmium	ppm	<0.21	<0.20	<0.12	<0.20	<0.20	<0.22
Calcium	ppm	92	91	180	95	95	128
Copper	ppm	<2.6	<2.5	1.5	5.1	2.6	2.7
Iron	ppm	2.6	15.5	100.4	2.6	15.7	4.0
Lead	ppm	<5.1	<5.1	<2.9	<5.1	<5.2	<5.4
Manganese	ppm	<1.5	<1.5	1.3	<1.5	<1.5	<1.6
Potassium	ppm	4.4	11.9	10.9	2.4	3.5	3.7
Sodium	ppm	10.3	9.6	14.0	5.4	10.3	12.0
Zinc	ppm	0.5	1.0	1.5	0.5	1.6	0.8
Oil and Grease	%						
pH		6.5		6.7	6.3	6.3	6.5

Table C-1 (continued)

Chemical Analyses on "A" Samples

Chemical Parameter	Units	A58TO					
Total Solids	%	0.046					
Total Nonvolatile Solids	%	0.035					
Total Volatile Solids	%	0.011					
Nonvolatile Suspended Solids	%						
Volatile Suspended Solids	%						
Nonvolatile Dissolved Solids	%						
Volatile Dissolved Solids	%						
Total Silica	%	0.006					
Chemical Oxygen Demand	mg/l	150					
Biochemical Oxygen Demand	mg/l	3					
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	<0.01					
Nitrate Nitrogen	ppm	8.0					
Total Phosphate	ppm						
Soluble Phosphate	ppm						
Cadmium	ppm	<0.11					
Calcium	ppm	148					
Copper	ppm	1.4					
Iron	ppm	5.5					
Lead	ppm	<2.7					
Manganese	ppm	<2.3					
Potassium	ppm	2.0					
Sodium	ppm	5.1					
Zinc	ppm	0.8					
Oil and Grease	%						
pH							

Table C-2

Chemical Analyses on "B" Sample

Chemical Parameter	Units	B12TO					
Total Solids	%	19.106					
Total Nonvolatile Solids	%	18.459					
Total Volatile Solids	%	0.647					
Nonvolatile Suspended Solids	%	18.431					
Volatile Suspended Solids	%	0.631					
Nonvolatile Dissolved Solids	%	0.028					
Volatile Dissolved Solids	%	0.016					
Total Silica	%	14.294					
Chemical Oxygen Demand	mg/l						
Biochemical Oxygen Demand	mg/l	380					
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.016					
Nitrate Nitrogen	ppm	0.176					
Total Phosphate	ppm						
Soluble Phosphate	ppm						
Cadmium	ppm	1.85					
Calcium	ppm	6,600					
Copper	ppm	9.2					
Iron	ppm	3,700					
Lead	ppm	11.5					
Manganese	ppm	29.3					
Potassium	ppm	335					
Sodium	ppm	187.5					
Zinc	ppm	29.4					
Oil and Grease	%						
pH		6.9					

Table C-3

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C29TO	C31TO	C34TO	C35TO	C38TO	C39TO
Total Solids	%	15.985	28.158	12.242	33.100	17.492	2.118
Total Nonvolatile Solids	%	14.746	25.949	11.204	30.770	15.982	1.881
Total Volatile Solids	%	1.239	2.210	1.038	2.330	1.511	0.237
Nonvolatile Suspended Solids	%	14.717	25.910	11.173	30.734	15.950	1.845
Volatile Suspended Solids	%	1.224	2.195	1.021	2.316	1.497	0.219
Nonvolatile Dissolved Solids	%	0.029	0.039	0.031	0.036	0.032	0.036
Volatile Dissolved Solids	%	0.015	0.015	0.017	0.014	0.014	0.018
Total Silica	%	11.391	19.918	8.313	22.984	11.579	1.414
Chemical Oxygen Demand	mg/l	25,000	36,700	27,000	36,500	25,500	13,000
Biochemical Oxygen Demand	mg/l	290	300	320	320	300	270
Total Nitrogen	ppm	107	162	95	196	115	
Ammonia Nitrogen	ppm	82	105	68	123	56	
Nitrite Nitrogen	ppm	0.121	0.011	0.090	0.009	0.155	0.029
Nitrate Nitrogen	ppm	0.357	0.189	0.197	0.243	0.309	1.419
Total Phosphate	ppm						132
Soluble Phosphate	ppm						0.164
Cadmium	ppm	<0.7	<0.6	<0.8	<0.5	<0.6	<0.1
Calcium	ppm	5,300	5,500	2,800	5,000	4,000	900
Copper	ppm	<7	<6	<8	<5	<6	8.4
Iron	ppm	5,600	5,800	4,100	5,400	5,700	700
Lead	ppm	14.4	11.6	<15	12.9	<13	<8
Manganese	ppm	75.7	91.3	64.3	96.6	70.7	13.7
Potassium	ppm	973	1,018	674	1,213	790	221
Sodium	ppm	97.3	122.1	191.4	54.2	86.8	41.1
Zinc	ppm	23.1	36.1	19.1	49.1	16.1	5.6
Oil and Grease	%	0.20	0.19	0.31	0.17	0.10	
pH							7.0

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C40TO	C41TO	C42TO	C43TO	C44TO	C45TO
Total Solids	%	20.937	11.412	8.140	11.921	6.683	12.613
Total Nonvolatile Solids	%	19.165	10.402	7.461	10.958	6.112	11.533
Total Volatile Solids	%	1.772	1.010	0.679	0.964	0.671	1.080
Nonvolatile Suspended Solids	%	19.133	10.368	7.434	10.926	6.074	11.506
Volatile Suspended Solids	%	1.746	0.994	0.661	0.945	0.557	1.056
Nonvolatile Dissolved Solids	%	0.032	0.034	0.027	0.032	0.038	0.027
Volatile Dissolved Solids	%	0.026	0.016	0.018	0.019	0.114	0.024
Total Silica	%	15.363			8.275	4.587	7.280
Chemical Oxygen Demand	mg/l	22,000	10,800	4,200	46,000	19,400	18,000
Biochemical Oxygen Demand	mg/l	1,040	470	120	350	450	140
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.012	0.111	0.005	0.101	0.023	0.031
Nitrate Nitrogen	ppm	0.142	0.487	1.791	0.335	0.233	0.437
Total Phosphate	ppm	29		82			120
Soluble Phosphate	ppm		0.216	0.118	0.180	0.157	0.077
Cadmium	ppm	0.58	0.54		0.29	0.25	0.57
Calcium	ppm	3,000	2,800		4,300	2,400	5,200
Copper	ppm	7.2	8.5		8.9	42.0	11.5
Iron	ppm	6,000	3,400		3,400	1,900	3,700
Lead	ppm	19.3	13.6		14.3	8.3	14.3
Manganese	ppm	84.3	56.3		57.2	35.0	65.9
Potassium	ppm	1,181	835		872	407	931
Sodium	ppm	110.8	84.8		80.8	58.5	89.6
Zinc	ppm	36.6	23.1		25.0	17.2	27.9
Oil and Grease	%						
pH		7.1	7.0	6.9	6.9	6.9	7.0

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C46TO	C47TO	C48TO	C49TO	C50TO	C51TO
Total Solids	%	3.963	4.273	1.446	11.390	7.254	4.258
Total Nonvolatile Solids	%	3.616	3.943	1.295	10.467	6.608	4.049
Total Volatile Solids	%	0.347	0.330	0.151	0.924	0.646	0.208
Nonvolatile Suspended Solids	%	3.577	3.908	1.258	10.431	6.575	4.009
Volatile Suspended Solids	%	0.335	0.318	0.137	0.916	0.628	0.198
Nonvolatile Dissolved Solids	%	0.039	0.035	0.037	0.036	0.033	0.040
Volatile Dissolved Solids	%	0.012	0.012	0.014	0.008	0.018	0.010
Total Silica	%	2.650	2.795	0.880	8.347	4.978	1.471
Chemical Oxygen Demand	mg/l	10,900	3,400	7,700	9,100	6,100	6,700
Biochemical Oxygen Demand	mg/l	240	110	100	150	300	70
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.019	0.062	0.025	0.013	0.005	0.053
Nitrate Nitrogen	ppm	0.096	1.512	0.227	0.709	1.298	0.546
Total Phosphate	ppm	153	121	52	297	242	80
Soluble Phosphate	ppm	0.307	0.237	0.201	0.181	0.226	0.195
Cadmium	ppm	0.29	0.34	0.14	0.28	0.33	0.12
Calcium	ppm	1,500	2,200	500	3,300	2,500	1,000
Copper	ppm	11.0	8.5	7.0	7.7	10.4	6.0
Iron	ppm	1,200	1,100	600	2,900	2,100	600
Lead	ppm	7.3	<9	<7	11.6	10.8	6.0
Manganese	ppm	21.6	22.6	10.1	54.0	39.8	13.0
Potassium	ppm	323	264	132	463	456	181
Sodium	ppm	46.9	47.8	30.3	89.1	68.0	38.1
Zinc	ppm	11.7	9.4	3.8	21.0	17.4	5.7
Oil and Grease	%						
pH		7.0	7.0	7.0	7.1	6.9	6.9

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C52TO	C53TO	C54TO	C55TO	C56TO	C57TO
Total Solids	%	25.299	9.422	5.836	8.029	4.320	14.962
Total Nonvolatile Solids	%	24.626	8.651	5.307	7.329	3.911	14.206
Total Volatile Solids	%	0.673	0.772	0.528	0.701	0.409	0.757
Nonvolatile Suspended Solids	%	24.595	8.610	5.268	7.289	3.880	14.169
Volatile Suspended Solids	%	0.669	0.768	0.517	0.697	0.397	0.753
Nonvolatile Dissolved Solids	%	0.031	0.041	0.039	0.040	0.031	0.037
Volatile Dissolved Solids	%	0.004	0.004	0.011	0.004	0.012	0.004
Total Silica	%	18.439	6.834	3.988	5.584	2.085	10.921
Chemical Oxygen Demand	mg/l	3,100	11,000	9,600	7,600	6,100	2,100
Biochemical Oxygen Demand	mg/l	50	190	220	190	100	35
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.041	0.027	0.024	0.055	0.019	0.034
Nitrate Nitrogen	ppm	0.710	0.272	0.160	0.782	0.096	0.765
Total Phosphate	ppm	431	272	201	266	107	96
Soluble Phosphate	ppm	0.096	0.116	<0.038	0.118	0.268	0.143
Cadmium	ppm	0.47	0.26	0.27	0.25	0.23	0.22
Calcium	ppm	11,700	2,500	1,800	1,600	800	5,700
Copper	ppm	8.2	6.5	6.8	28.9	57.1	7.7
Iron	ppm	4,400	2,000	1,600	2,500	1,000	2,700
Lead	ppm	42.7	13.1	8.8	10.3	9.4	14.2
Manganese	ppm	76.0	46.4	31.2	41.1	19.4	54.1
Potassium	ppm	526	356	434	442	245	464
Sodium	ppm	146.2	71.8	51.6	59.2	33.1	103.1
Zinc	ppm	31.0	18.9	14.3	18.7	10.8	18.6
Oil and Grease	%						
pH		6.8	7.1	7.0	7.0	7.1	6.9

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C58TO	C59TO	C60TO	C61TO	C64TO	C65TO
Total Solids	%	3.418	8.610	6.992	8.850	13.574	24.909
Total Nonvolatile Solids	%	3.092	7.952	6.404	8.128	12.540	23.940
Total Volatile Solids	%	0.325	0.659	0.588	0.722	1.034	0.969
Nonvolatile Suspended Solids	%	3.048	7.911	6.367	8.087	12.500	23.911
Volatile Suspended Solids	%	0.321	0.657	0.584	0.718	1.030	0.965
Nonvolatile Dissolved Solids	%	0.044	0.041	0.037	0.041	0.040	0.029
Volatile Dissolved Solids	%	0.004	0.002	0.004	0.004	0.004	0.004
Total Silica	%	2.221	5.978	4.821	6.130	9.506	18.550
Chemical Oxygen Demand	mg/l	6,000	10,200				3,900
Biochemical Oxygen Demand	mg/l	120	140	140	160	140	70
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.058	0.032	0.019	0.050	0.035	0.015
Nitrate Nitrogen	ppm	0.802	0.128	0.102	2.096	0.173	0.238
Total Phosphate	ppm	135	249	238	265	338	501
Soluble Phosphate	ppm	0.197	0.117	0.156	0.117	0.111	0.066
Cadmium	ppm	0.11	0.24	0.23	0.21	0.41	0.45
Calcium	ppm	700	1,400	2,000	3,800	5,100	7,800
Copper	ppm	5.4	6.1	5.8	5.1	6.4	7.0
Iron	ppm	1,000	2,500	2,400	2,500	4,000	3,600
Lead	ppm	5.4	12.2	5.8	10.3	14.1	20.0
Manganese	ppm	19.9	45.2	38.5	44.7	58.8	69.6
Potassium	ppm	289	477	408	452	511	367
Sodium	ppm	38.1	65.4	64.1	62.6	86.9	94.6
Zinc	ppm	8.2	15.9	14.6	16.7	19.9	21.7
Oil and Grease	%						
pH		6.9	7.0	7.0	6.9	6.8	6.9

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C66TO	C67TO	C68TO	C69TO	C72TO	C73TO
Total Solids	%	17.765	30.625	3.754	5.178	27.129	14.462
Total Nonvolatile Solids	%	16.749	28.832	3.434	4.798	26.525	14.322
Total Volatile Solids	%	1.016	1.794	0.321	0.379	1.004	0.140
Nonvolatile Suspended Solids	%	16.719	28.803	3.397	4.762	26.083	14.286
Volatile Suspended Solids	%	1.010	1.792	0.318	0.375	0.984	0.121
Nonvolatile Dissolved Solids	%	0.030	0.029	0.037	0.036	0.442	0.036
Volatile Dissolved Solids	%	0.006	0.002	0.003	0.004	0.020	0.019
Total Silica	%	12.761	23.136	2.493	3.461	21.427	11.740
Chemical Oxygen Demand	mg/l	6,100	6,300		2,700	24,200	
Biochemical Oxygen Demand	mg/l	50	70	80	16		30
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.016	0.017	0.043	0.033	0.011	
Nitrate Nitrogen	ppm	0.164	0.428	0.318	0.632	0.158	5.817
Total Phosphate	ppm	418	397	397	124	356	333
Soluble Phosphate	ppm	0.230	0.142	0.235	0.265	0.122	0.109
Cadmium	ppm	0.38	0.51	0.12	0.22	1.54	1.45
Calcium	ppm	5,700	6,900	1,900	1,500	5,600	4,900
Copper	ppm	6.7	6.8	6.2	5.9	9.6	9.4
Iron	ppm	3,900	6,200	1,100	1,200	5,400	4,500
Lead	ppm	15.0	21.2	6.2	7.0	14.1	13.3
Manganese	ppm	64.1	75.6	22.6	23.7	97.5	88.1
Potassium	ppm	485		272	242	281	262
Sodium	ppm	90 3	127.4	38.0	37.7	112.6	187.5
Zinc	ppm	20 2	37.8	8.4	9.1	35.3	33.9
Oil and Grease	%						
pH		7.0	6.8	6.9	6.9	6.7	6.8

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C74TO	C76TO	C77TO	C79TO	C80TO	C81TO
Total Solids	%	17.204	1.538	17.8653	11.719	22.557	29.687
Total Nonvolatile Solids	%	16.642	1.473	17.226	11.349	21.718	28.577
Total Volatile Solids	%	0.562	0.067	0.639	0.370	0.839	1.111
Nonvolatile Suspended Solids	%	16.595	1.452	17.197	11.331	21.687	28.550
Volatile Suspended Solids	%	0.546	0.040	0.630	0.350	0.818	1.097
Nonvolatile Dissolved Solids	%	0.047	0.021	0.029	0.018	0.031	0.027
Volatile Dissolved Solids	%	0.016	0.027	0.009	0.020	0.021	0.014
Total Silica	%	12.653	1.027	14.97	8.769	16.988	22.525
Chemical Oxygen Demand	mg/l		900	100		17,800	
Biochemical Oxygen Demand	mg/l	480			110		
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.017	0.266	0.025	0.163	0.015	0.067
Nitrate Nitrogen	ppm	0.166	5.612	0.164	0.677	0.155	0.364
Total Phosphate	ppm	107	46	312	125	284	463
Soluble Phosphate	ppm	0.106	0.126	0.105	0.148	0.189	0.118
Cadmium	ppm	<1	<1.2	1.42	1.28	1.41	1.82
Calcium	ppm	5,600	1,100	4,000	4,700	6,700	7,300
Copper	ppm	4.9	<6	5.0	6.2	6.5	10.1
Iron	ppm	1,500	600	2,500	2,300	3,500	4,900
Lead	ppm	4.9	<6	7.3	7.8	10.5	14.2
Manganese	ppm	39.8	9.8	58.5	52.1	90.8	107.9
Potassium	ppm	78	43	170	194	258	326
Sodium	ppm	127.8	32.9	128.4	118.3	104.9	115.1
Zinc	ppm	7.8	3.3	14.8	14.4	39.1	36.0
Oil and Grease	%						
pH		7.0	6.8	6.4	6.9	6.8	7.0

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C83TO	C84TO	C85TO	C86TO	C87TO	C88TO
Total Solids	%	36.375	35.895	47.083	47.546	34.538	31.474
Total Nonvolatile Solids	%	35.141	34.395	45.789	46.032	32.768	30.003
Total Volatile Solids	%	1.235	1.500	1.295	1.514	1.769	1.472
Nonvolatile Suspended Solids	%	35.115	34.367	45.760	46.006	32.765	30.002
Volatile Suspended Solids	%	1.221	1.484	1.285	1.505	1.764	1.470
Nonvolatile Dissolved Solids	%	0.026	0.028	0.029	0.026	0.003	0.001
Volatile Dissolved Solids	%	0.014	0.016	0.010	0.009	0.005	0.002
Total Silica	%	29.881	34.232	35.917	35.965		
Chemical Oxygen Demand	mg/l	31,100					
Biochemical Oxygen Demand	mg/l						
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.010	0.010	0.008	0.021		
Nitrate Nitrogen	ppm	0.138	0.181	0.115	0.131		
Total Phosphate	ppm	801	380	324	723		
Soluble Phosphate	ppm	0.107	0.082	0.047	0.067		
Cadmium	ppm	1.32	1.79	1.16	1.23		
Calcium	ppm	7,600	7,400	7,200	5,200		
Copper	ppm	6.7	13.0	5.2	8.2		
Iron	ppm	3,900	5,100	2,200	3,600		
Lead	ppm	14.2	22.9	10.7	13.1		
Manganese	ppm	122.9	229.9	96.9	85.2		
Potassium	ppm	264	309	195	215		
Sodium	ppm	128.5	236.3	99.4	157.3		
Zinc	ppm	31.8	57.2	24.2	38.0		
Oil and Grease	%						
pH		6.7	7.0	7.1	6.9		

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C89TO	C90TO	C91TO	C92TO	C93TO	C94TO
Total Solids	%	36.030	36.957	30.238	30.603	27.431	30.147
Total Nonvolatile Solids	%	34.331	34.096	28.724	28.653	26.427	28.958
Total Volatile Solids	%	1.653	1.861	1.514	1.951	1.004	1.119
Nonvolatile Suspended Solids	%	34.321	34.086	28.718	28.649	26.391	28.922
Volatile Suspended Solids	%	1.627	1.838	1.486	1.920	0.988	1.105
Nonvolatile Dissolved Solids	%	0.010	0.010	0.006	0.004	0.036	0.036
Volatile Dissolved Solids	%	0.026	0.023	0.028	0.031	0.016	0.014
Total Silica	%					20.833	20.523
Chemical Oxygen Demand	mg/l					24,300	29,400
Biochemical Oxygen Demand	mg/l					1,510	1,910
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm						
Nitrate Nitrogen	ppm					0.018	0.011
Total Phosphate	ppm					0.157	0.163
Soluble Phosphate	ppm					696	412
Cadmium	ppm					0.109	0.143
Calcium	ppm					1.74	1.70
Copper	ppm					7,500	6,500
Iron	ppm					11.2	7.2
Lead	ppm					5,400	3,600
Manganese	ppm					14.7	11.6
Potassium	ppm					111.8	94.0
Sodium	ppm					358	277
Zinc	ppm					119.2	123.0
Oil and Grease	%					37.3	37.6
pH						6.9	6.7

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C95TO	C96TO	C97TO	C98TO	C99TO	C100TO
Total Solids	%	27.101	24.110	23.874	22.983	42.151	24.012
Total Nonvolatile Solids	%	26.164	23.017	22.616	21.921	39.935	22.729
Total Volatile Solids	%	0.937	1.094	1.257	1.062	2.216	1.283
Nonvolatile Suspended Solids	%	26.127	23.009	22.615	21.920	39.935	22.727
Volatile Suspended Solids	%	0.921	1.068	1.257	1.045	2.210	1.257
Nonvolatile Dissolved Solids	%	0.037	0.008	0.001	0.001	0.000	0.002
Volatile Dissolved Solids	%	0.016	0.026	0.000	0.017	0.006	0.026
Total Silica	%	22.046					
Chemical Oxygen Demand	mg/l	26,600					
Biochemical Oxygen Demand	mg/l	1,940					
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.015					
Nitrate Nitrogen	ppm	0.170					
Total Phosphate	ppm	529					
Soluble Phosphate	ppm	0.127					
Cadmium	ppm	1.69					
Calcium	ppm	8,200					
Copper	ppm	7.7					
Iron	ppm	4,000					
Lead	ppm	11.9					
Manganese	ppm	98.9					
Potassium	ppm	312					
Sodium	ppm	89.9					
Zinc	ppm	33.3					
Oil and Grease	%						
pH		6.7					

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C101TO	C102TO	C103TO	C104TO	C105TO	C106TO
Total Solids	%	26.420	22.369	32.329	20.082	15.278	17.000
Total Nonvolatile Solids	%	25.202	19.435	28.183	17.530	13.304	14.821
Total Volatile Solids	%	1.218	2.934	4.196	2.551	1.974	2.179
Nonvolatile Suspended Solids	%	25.192	19.400	28.160	17.507	13.272	14.796
Volatile Suspended Solids	%	1.193	2.912	4.186	2.540	1.958	2.164
Nonvolatile Dissolved Solids	%	0.010	0.035	0.023	0.023	0.032	0.025
Volatile Dissolved Solids	%	0.025	0.022	0.010	0.011	0.016	0.015
Total Silica	%		16.670	24.647	14.461	11.009	13.662
Chemical Oxygen Demand	mg/l		19,700	17,200	19,600	11,600	21,000
Biochemical Oxygen Demand	mg/l		250	230	350	170	350
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm		0.004	0.054	0.020	0.051	<0.004
Nitrate Nitrogen	ppm		0.085	0.372	0.168	0.110	0.133
Total Phosphate	ppm		623		489		521
Soluble Phosphate	ppm						
Cadmium	ppm		0.68	0.43	0.49	0.24	0.47
Calcium	ppm		5,700	6,500	4,900	4,000	4,400
Copper	ppm		6.1	8.0	13.9	7.3	4.7
Iron	ppm		4,200	4,300	4,300	3,600	3,200
Lead	ppm		11.8	15.8	12.7	9.7	9.4
Manganese	ppm		99.6	127.6	96.8	70.0	72.8
Potassium	ppm		987	1,147	1,003	811	681
Sodium	ppm		199.2	259.6	220.1	176.1	159.7
Zinc	ppm		2.7	2.9	2.7	22.7	18.9
Oil and Grease	%						
pH			6.6	6.7	6.9	6.6	6.9

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C107TO	C108TO	C109TO	C110TO	C111TO	C112TO
Total Solids	%	8.366	21.385	8.331	15.613	10.494	13.826
Total Nonvolatile Solids	%	7.099	18.663	7.241	13.589	9.127	12.036
Total Volatile Solids	%	1.266	2.723	1.090	2.025	1.367	1.790
Nonvolatile Suspended Solids	%	7.067	18.631	7.207	13.554	9.127	11.997
Volatile Suspended Solids	%	1.255	2.708	1.078	2.010	1.367	1.752
Nonvolatile Dissolved Solids	%	0.032	0.032	0.034	0.035		0.039
Volatile Dissolved Solids	%	0.011	0.015	0.012	0.015		0.038
Total Silica	%	15.973	15.950	5.863	11.481		9.767
Chemical Oxygen Demand	mg/l	12,000	19,400	6,200	19,900	11,900	14,400
Biochemical Oxygen Demand	mg/l	190	380	210	280	400	510
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.137	0.056	0.014	0.011		0.012
Nitrate Nitrogen	ppm	0.357	0.236	0.138	0.186		0.138
Total Phosphate	ppm		763		444		615
Soluble Phosphate	ppm						
Cadmium	ppm	<0.22	0.56	<0.24	0.24	0.26	0.71
Calcium	ppm	1,900	4,000	2,400	4,000	3,300	3,500
Copper	ppm	4.5	3.8	5.1	6.5	4.4	7.1
Iron	ppm	1,600	3,800	2,600	3,000	2,400	4,200
Lead	ppm	5.4	12.4	8.1	9.6	8.8	12.0
Manganese	ppm	26.9	101.7	41.0	86.0	45.7	66.4
Potassium	ppm	399	1,017	603	678	557	940
Sodium	ppm	66.8	173.2	98.3	141.0	105.7	178.8
Zinc	ppm	8.1	3.3	11.7	16.2	28.6	29.6
Oil and Grease	%						
pH		6.8	6.9	6.9	6.7	6.6	6.8

Table C-3 (continued)

Chemical Analyses on "C" Samples

Chemical Parameter	Units	C113TO	C114TO	C115TO			
Total Solids	%	4.095	9.044	5.246			
Total Nonvolatile Solids	%	3.504	8.082	4.708			
Total Volatile Solids	%	0.591	0.962	0.539			
Nonvolatile Suspended Solids	%	3.472	8.042	4.676			
Volatile Suspended Solids	%	0.573	0.938	0.525			
Nonvolatile Dissolved Solids	%	0.032	0.040	0.032			
Volatile Dissolved Solids	%	0.018	0.024	0.014			
Total Silica	%	2.853	6.436	3.708			
Chemical Oxygen Demand	mg/l	5,000					
Biochemical Oxygen Demand	mg/l						
Total Nitrogen	ppm						
Ammonia Nitrogen	ppm						
Nitrite Nitrogen	ppm	0.010	0.009	0.011			
Nitrate Nitrogen	ppm	0.153	0.155	0.142			
Total Phosphate	ppm		380				
Soluble Phosphate	ppm						
Cadmium	ppm	<0.23	0.27	<0.17			
Calcium	ppm	1,200	2,700	1,400			
Copper	ppm	2.7	5.4	2.8			
Iron	ppm	1,200	2,700	1,500			
Lead	ppm	5.8	9.2	5.8			
Manganese	ppm	20.4	46.4	27.8			
Potassium	ppm	298	674	441			
Sodium	ppm	40.9	115.9	58.6			
Zinc	ppm	9.8	12.9	8.0			
Oil and Grease	%						
pH		6.8	6.7	6.7			

APPENDIX D

GRAPHICAL COMPARISONS OF INFLUENT-EFFLUENT QUALITY

The data tabulated in Appendix C were averaged on a daily basis (that is, the results obtained from all samples taken in any given day were averaged), and the results are presented in graphical form in Figures D-1 through D-16. Any test value which was lower than the minimum limit of accuracy of the test procedure was considered to be equal to the minimum significance level of the test.

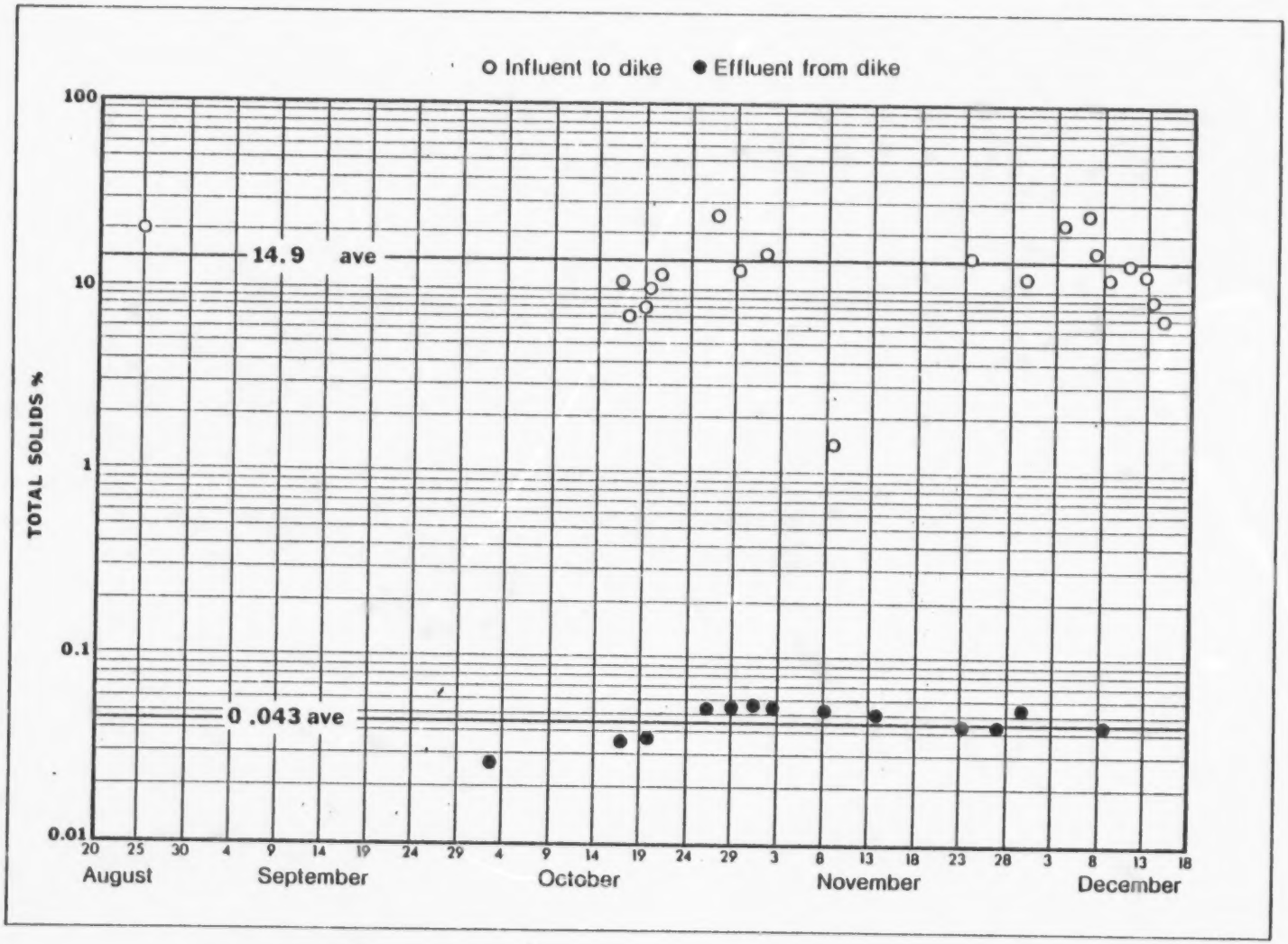


Figure D-1. Comparison of Influent-Effluent Quality for Total Solids

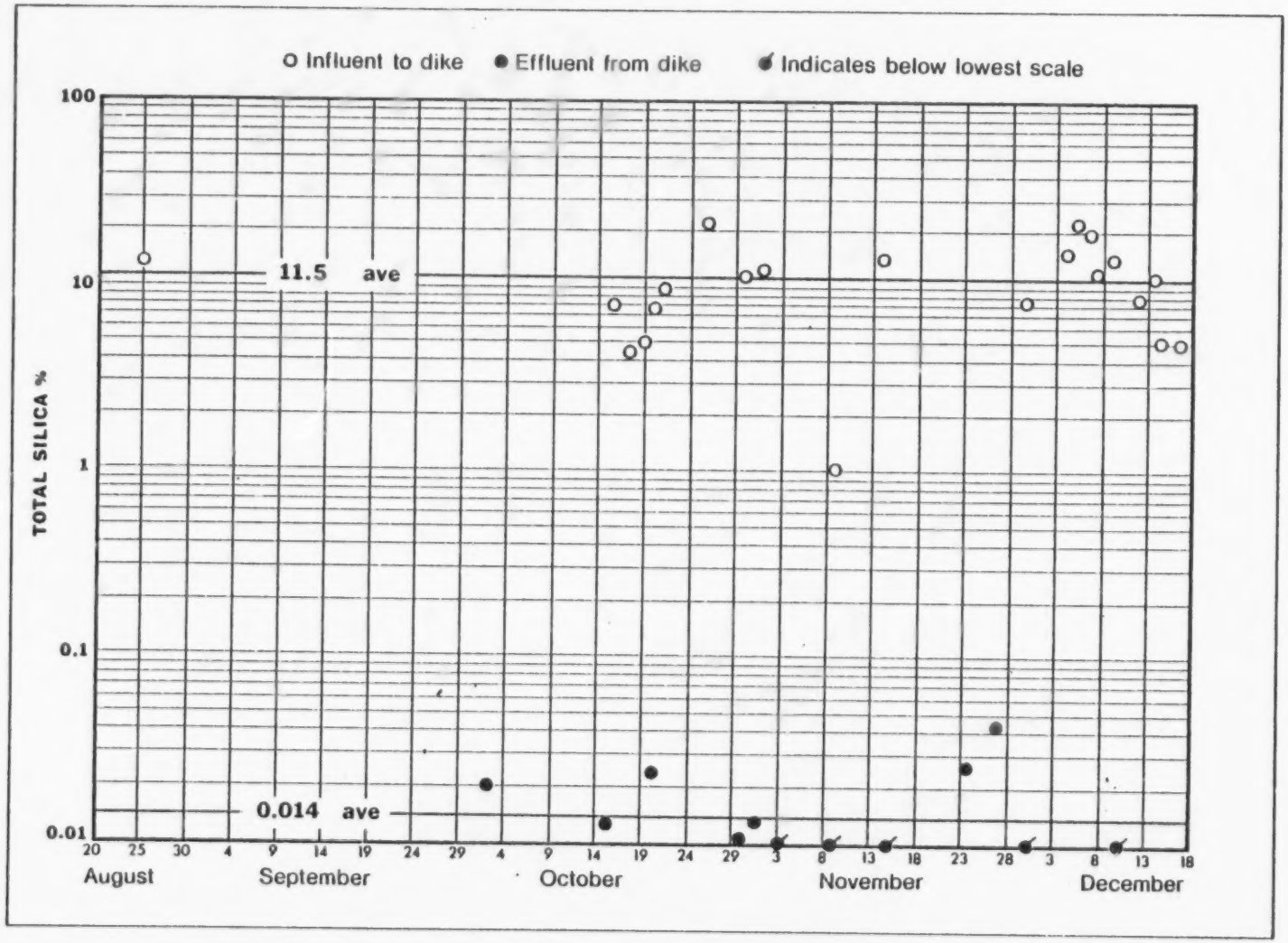


Figure D-2. Comparison of Influent-Effluent Quality for Total Silica

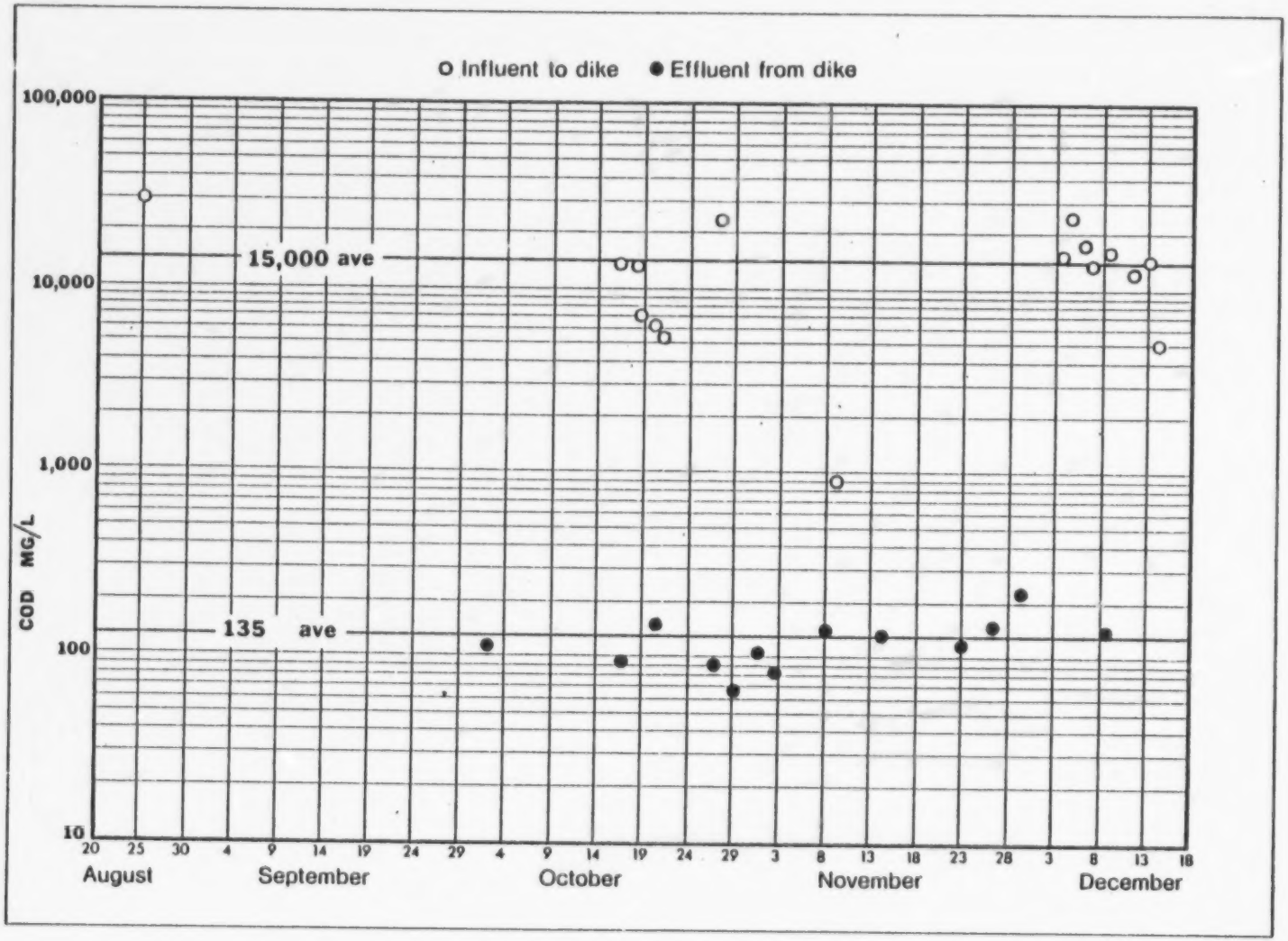


Figure D-3. Comparison of Influent-Effluent Quality for Chemical Oxygen Demand

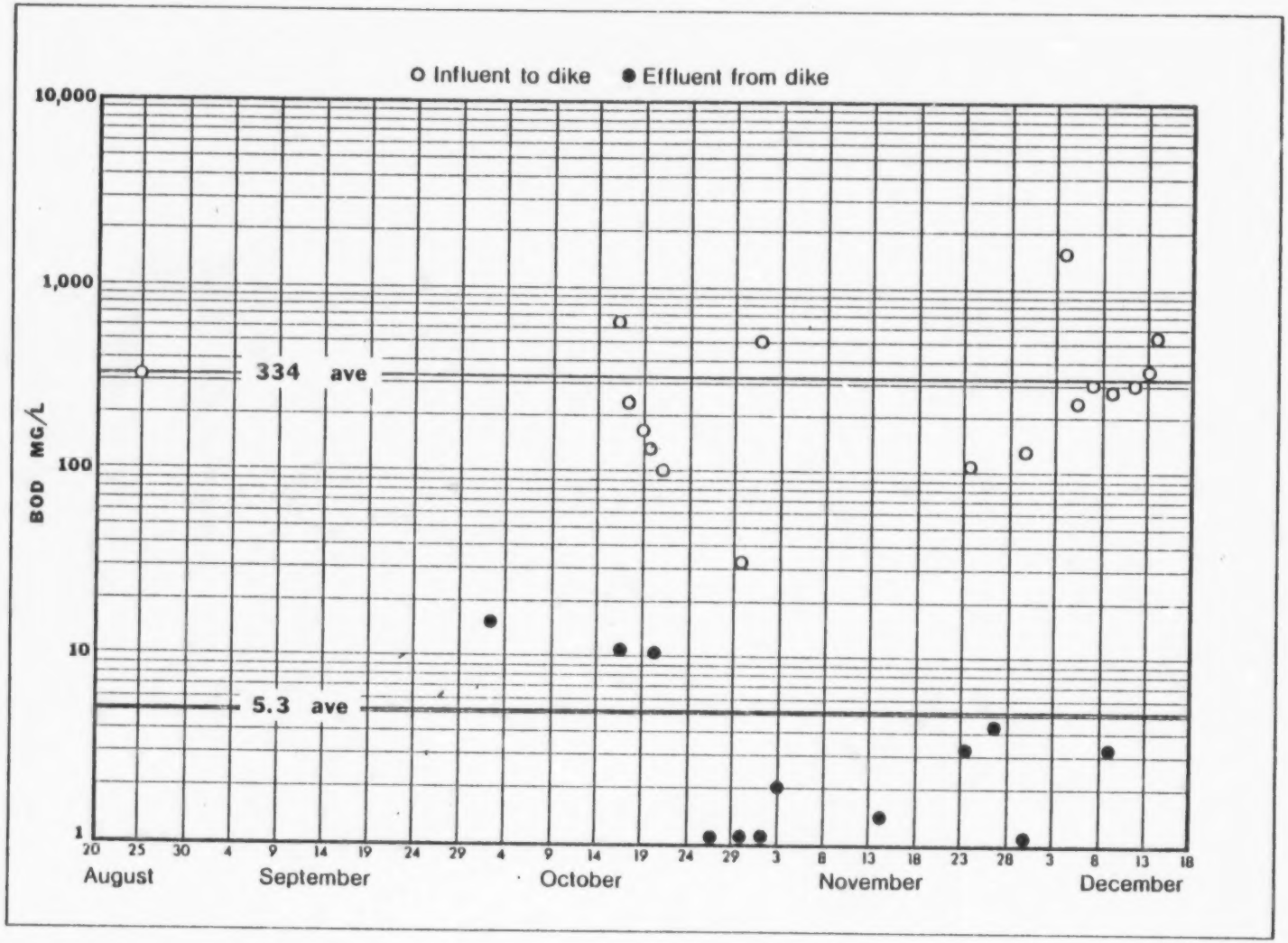


Figure D-4. Comparison of Influent-Effluent Quality for Biochemical Oxygen Demand

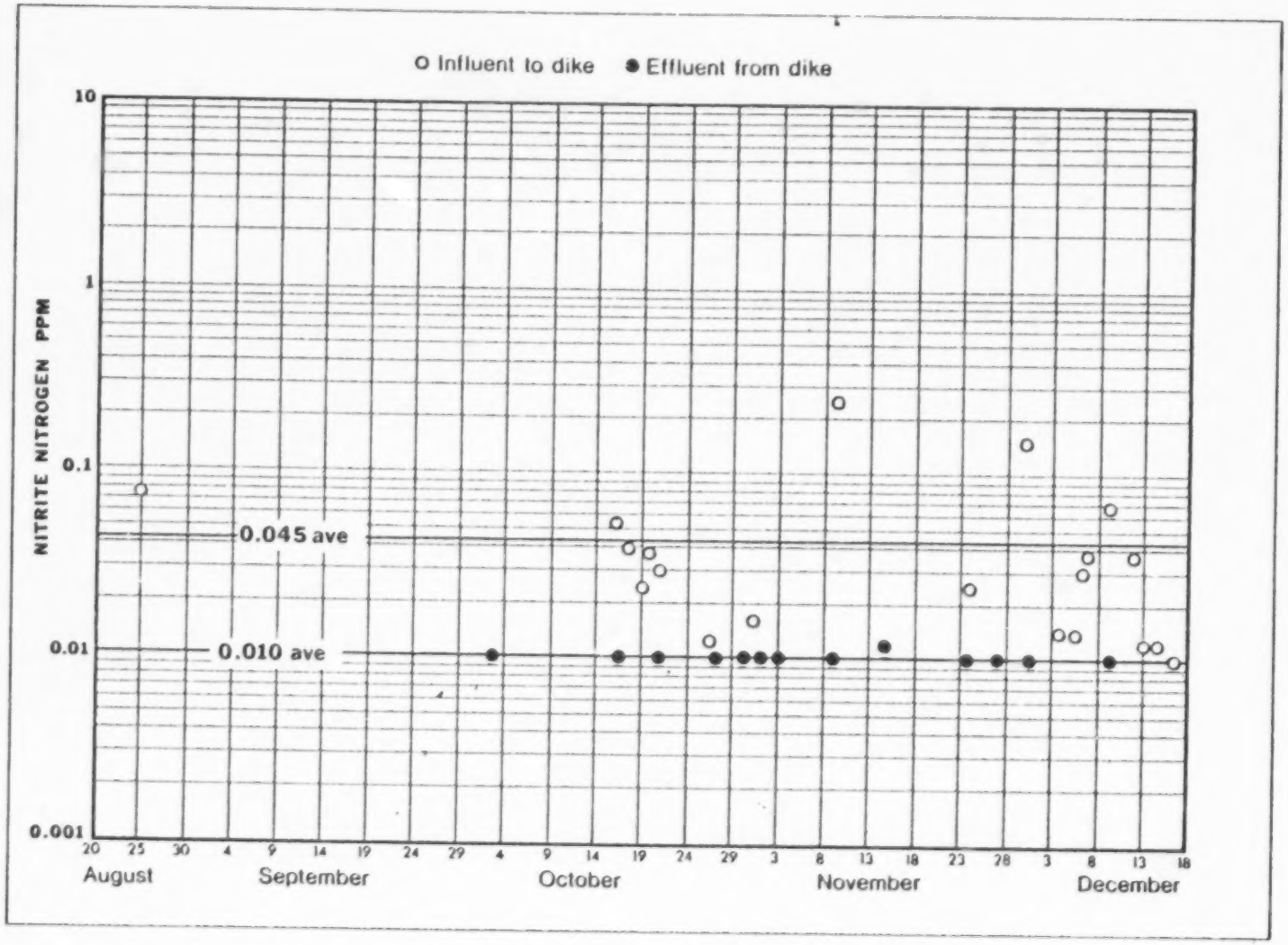


Figure D-5. Comparison of Influent-Effluent Quality for Nitrite Nitrogen

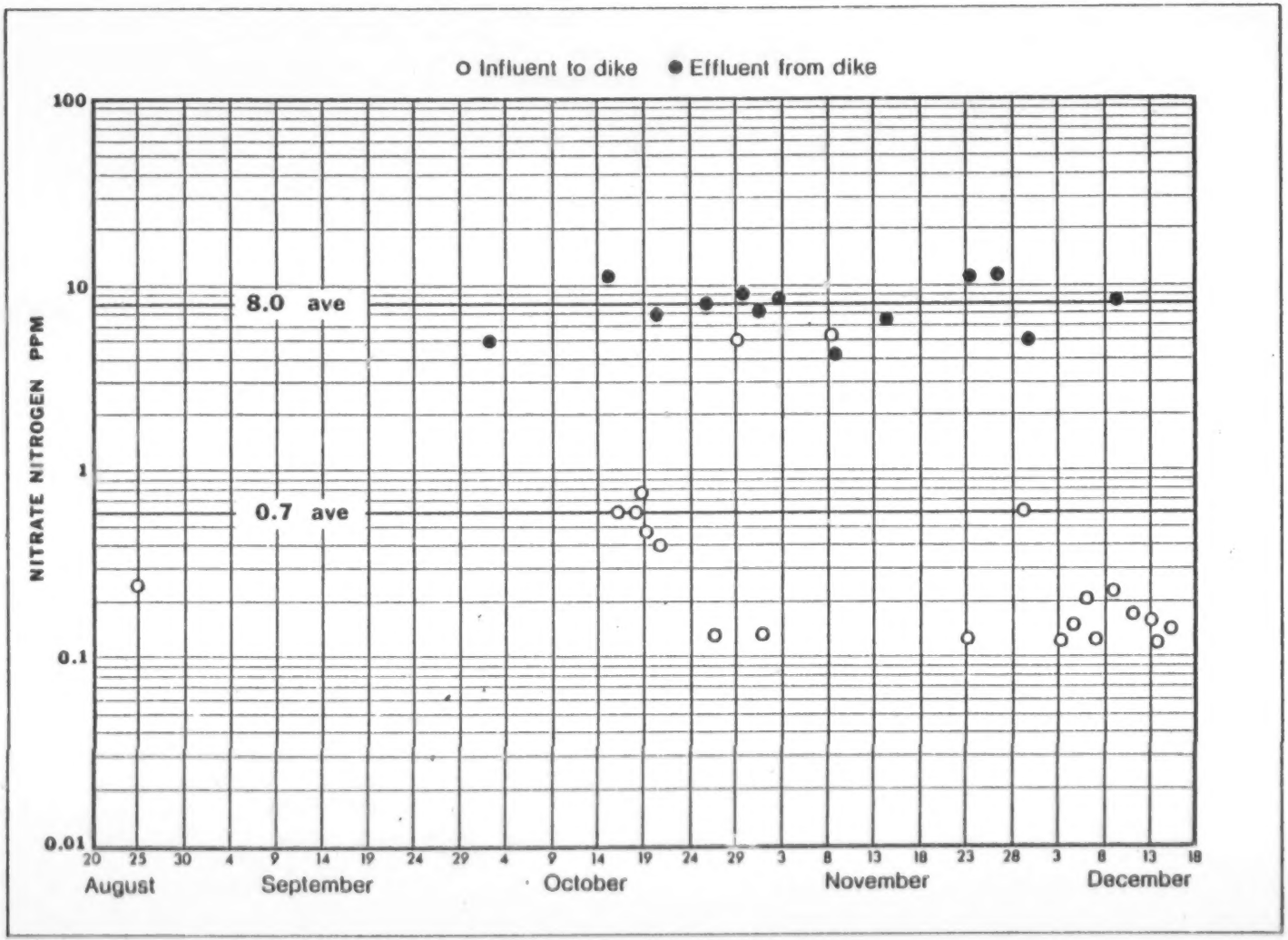


Figure D-6. Comparison of Influent-Effluent Quality for Nitrate Nitrogen

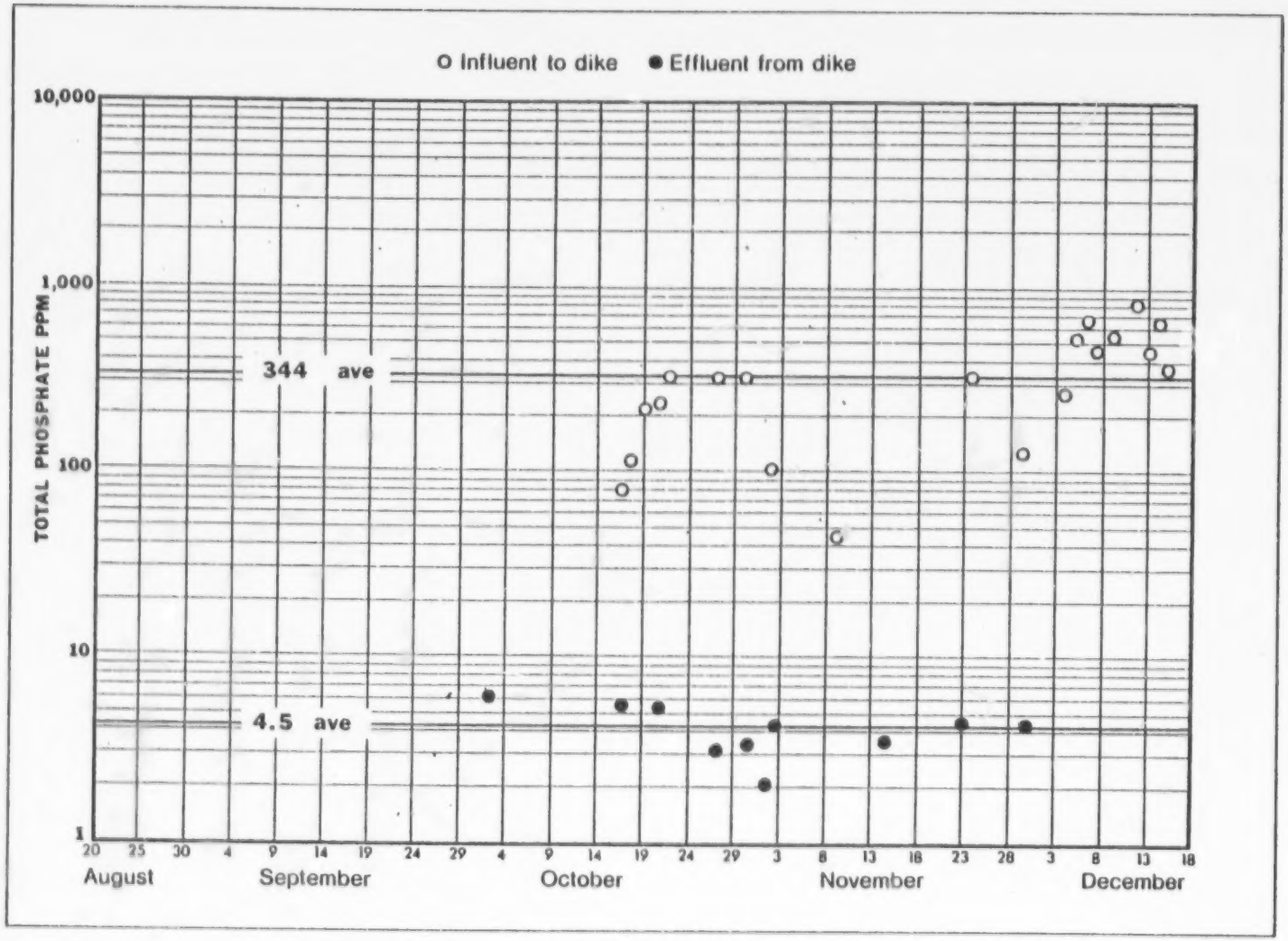


Figure D-7. Comparison of Influent-Effluent Quality for Total Phosphate

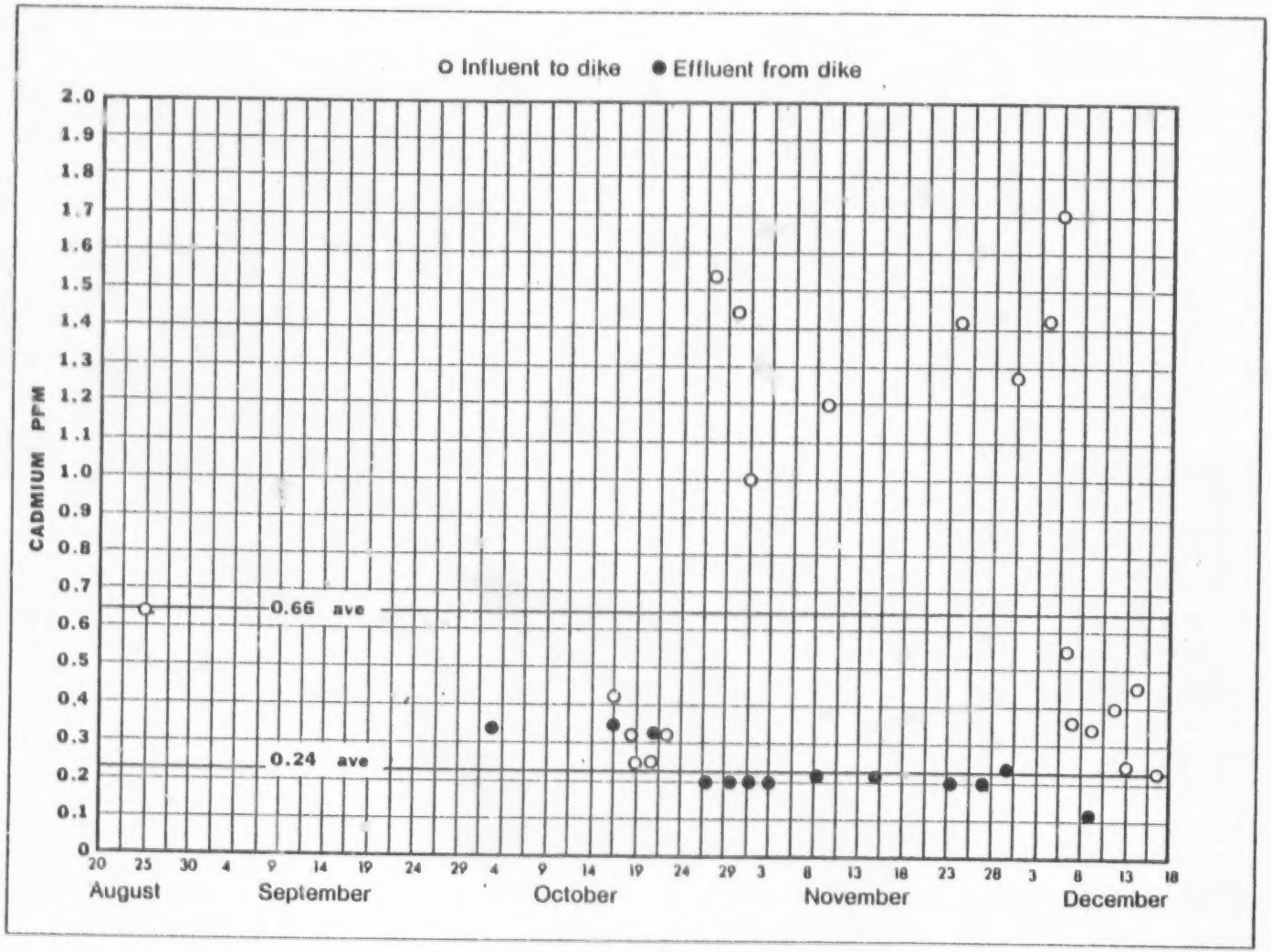


Figure D-8. Comparison of Influent-Effluent Quality for Cadmium

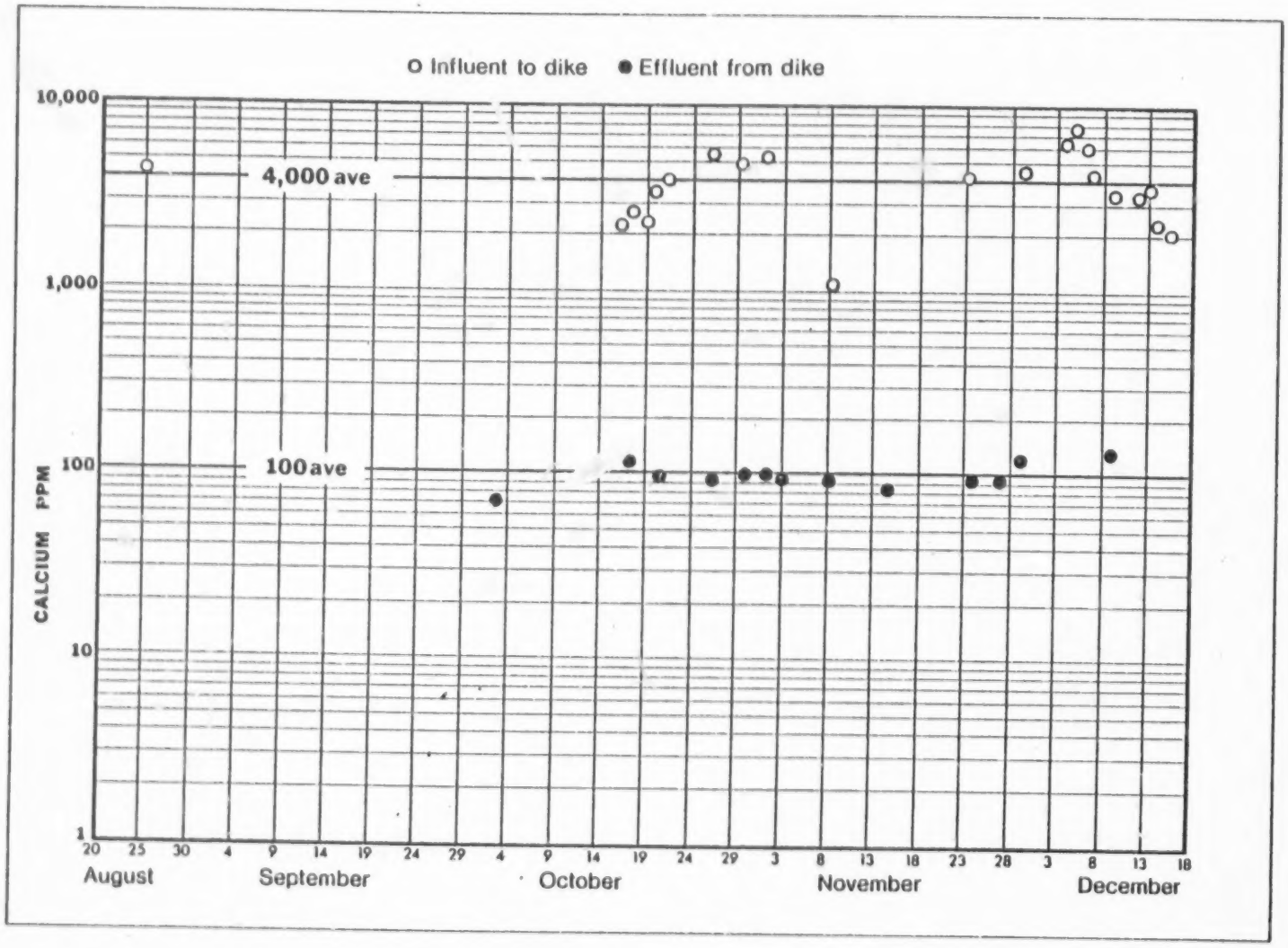


Figure D-9. Comparison of Influent-Effluent Quality for Calcium

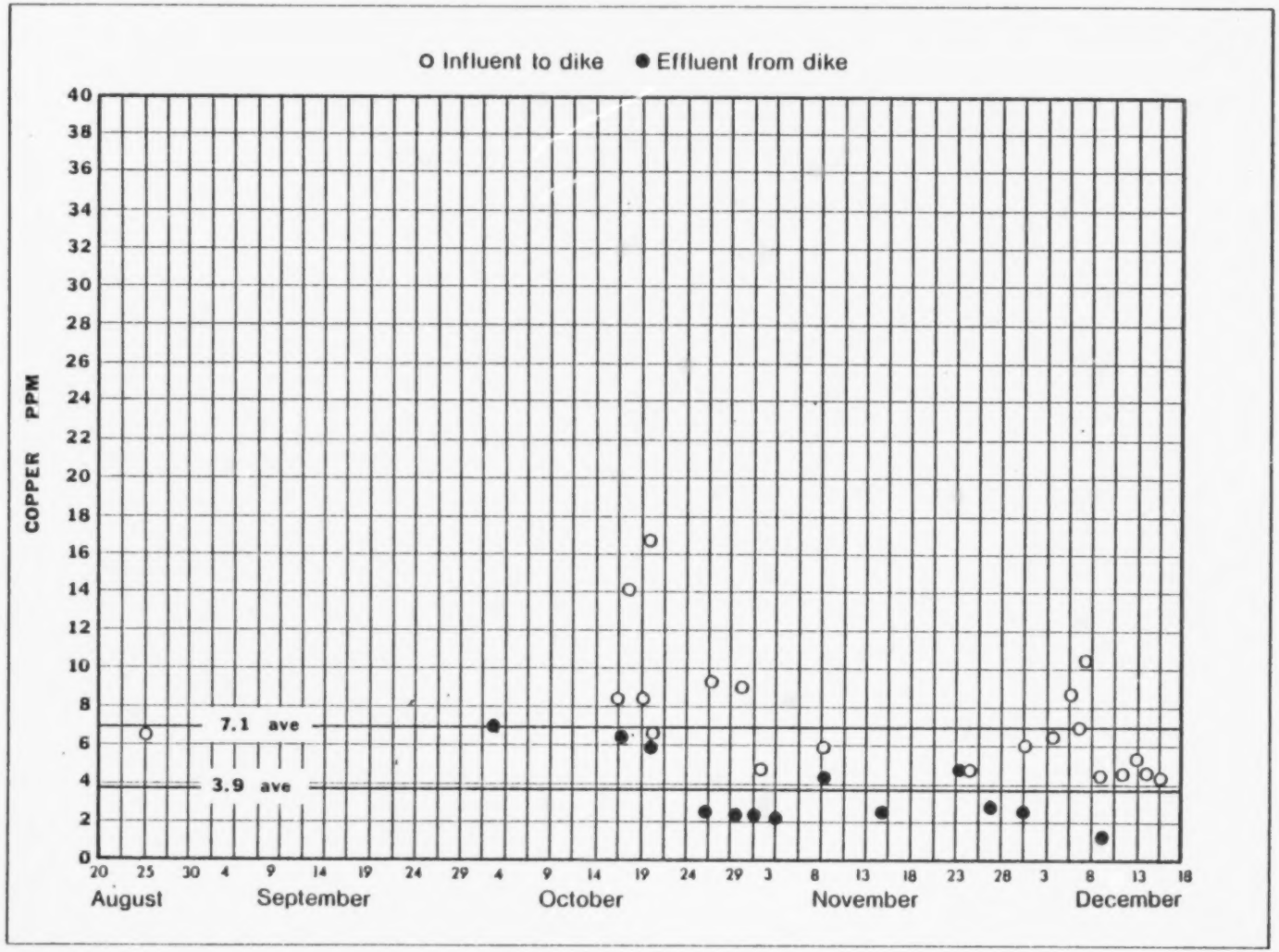


Figure D-10. Comparison of Influent-Effluent Quality for Copper

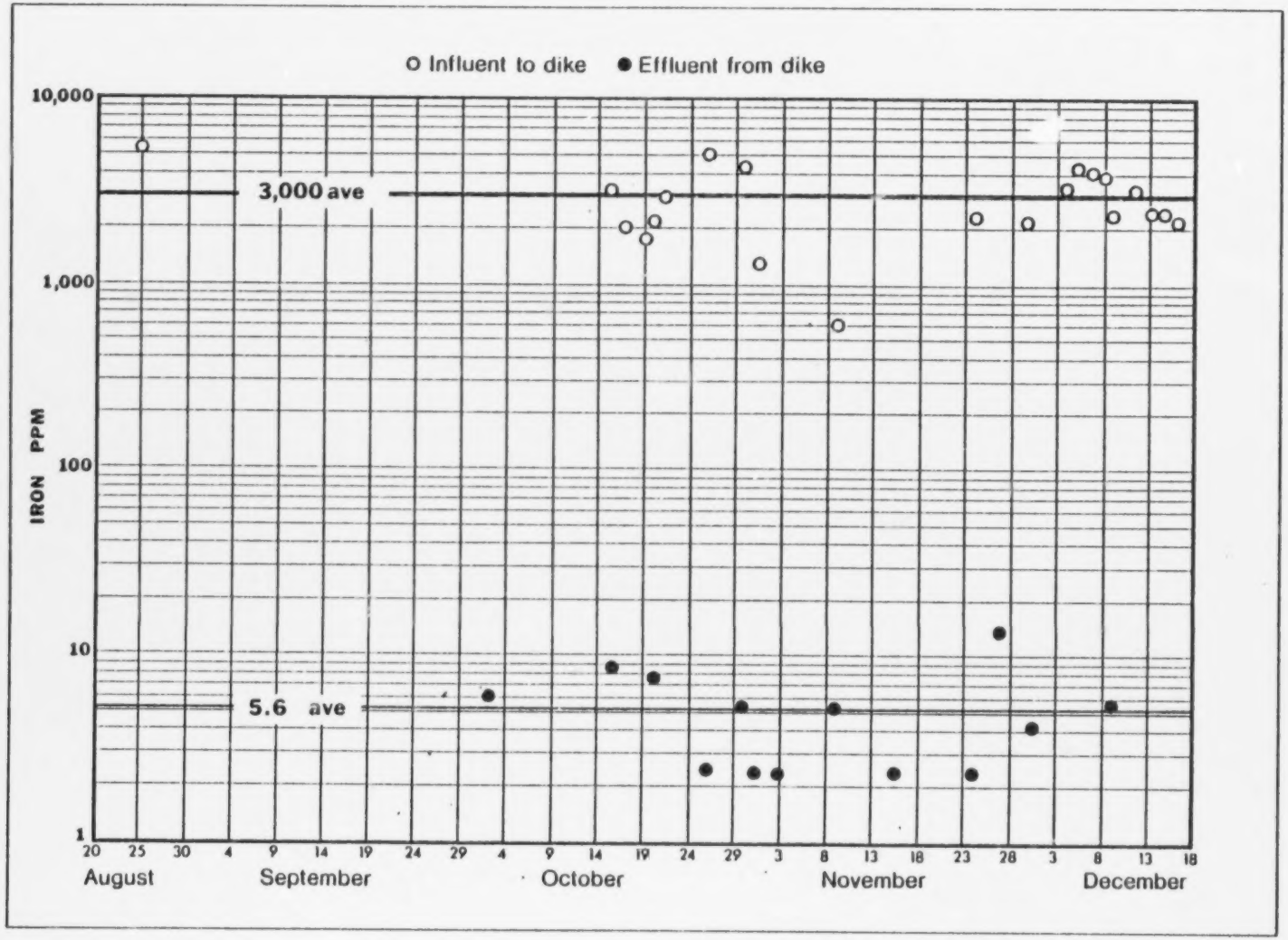


Figure D-11. Comparison of Influent-Effluent Quality for Iron

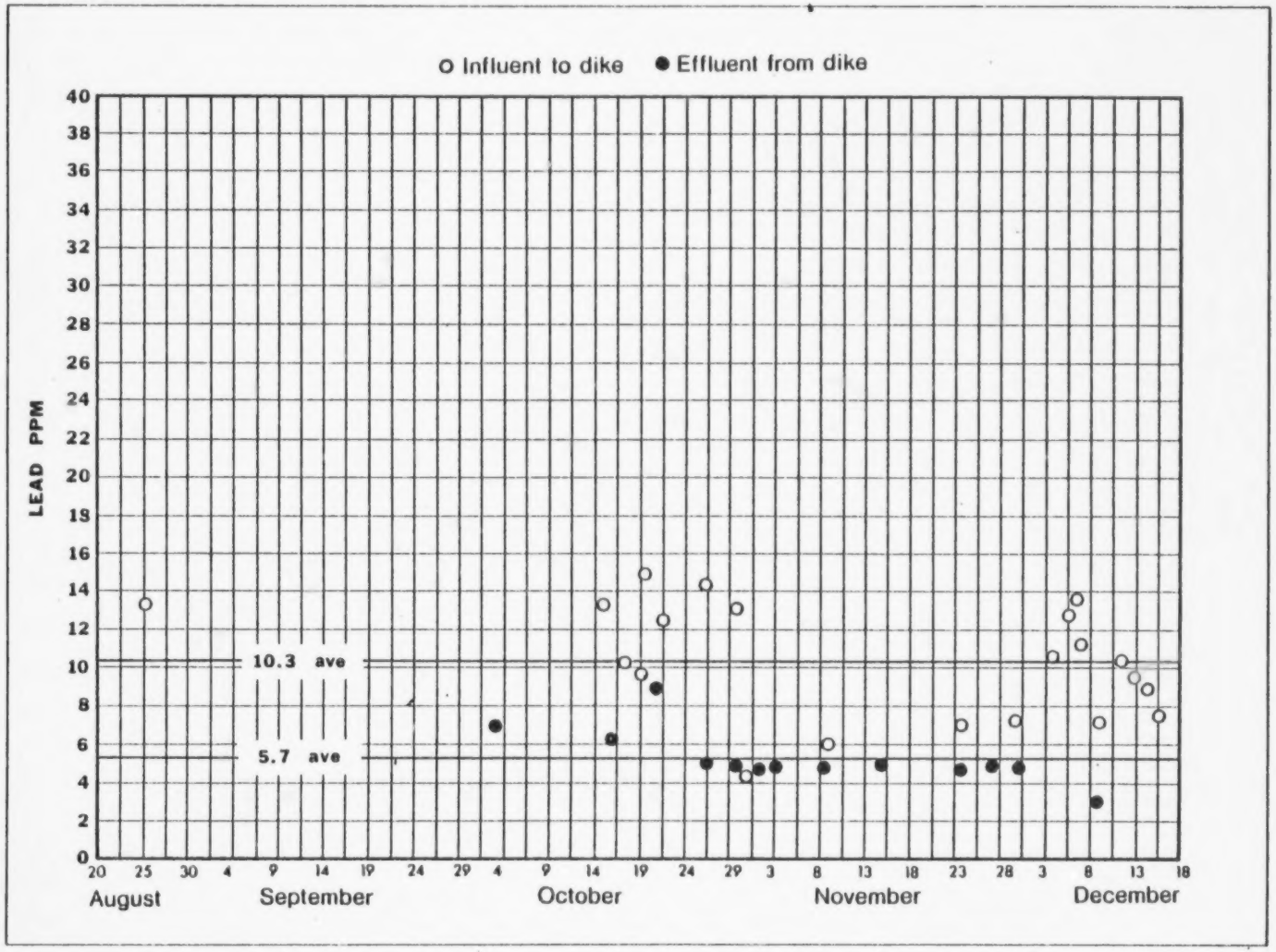


Figure D-12. Comparison of Influent-Effluent Quality for Lead

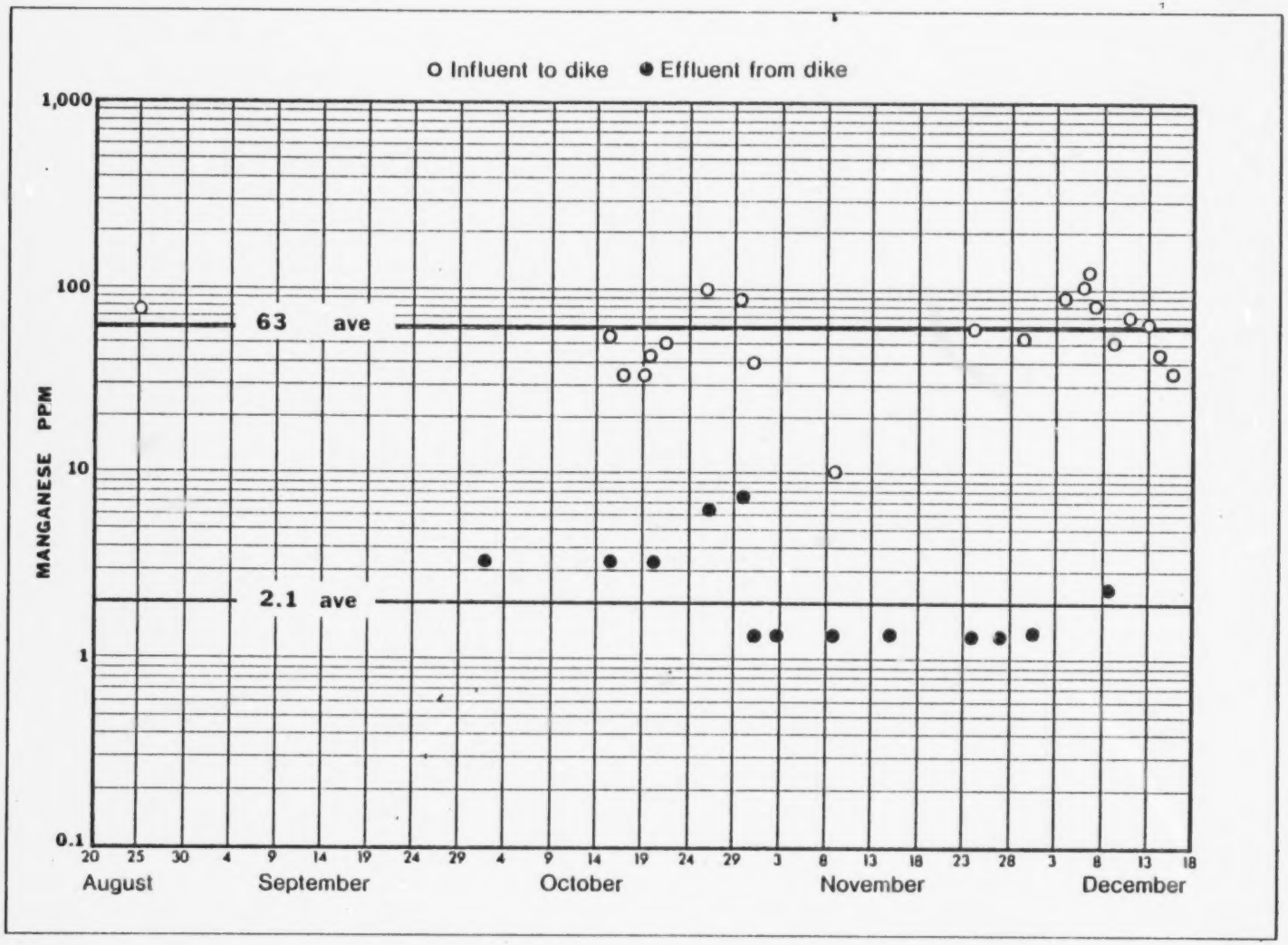


Figure D-13. Comparison of Influent-Effluent Quality for Manganese

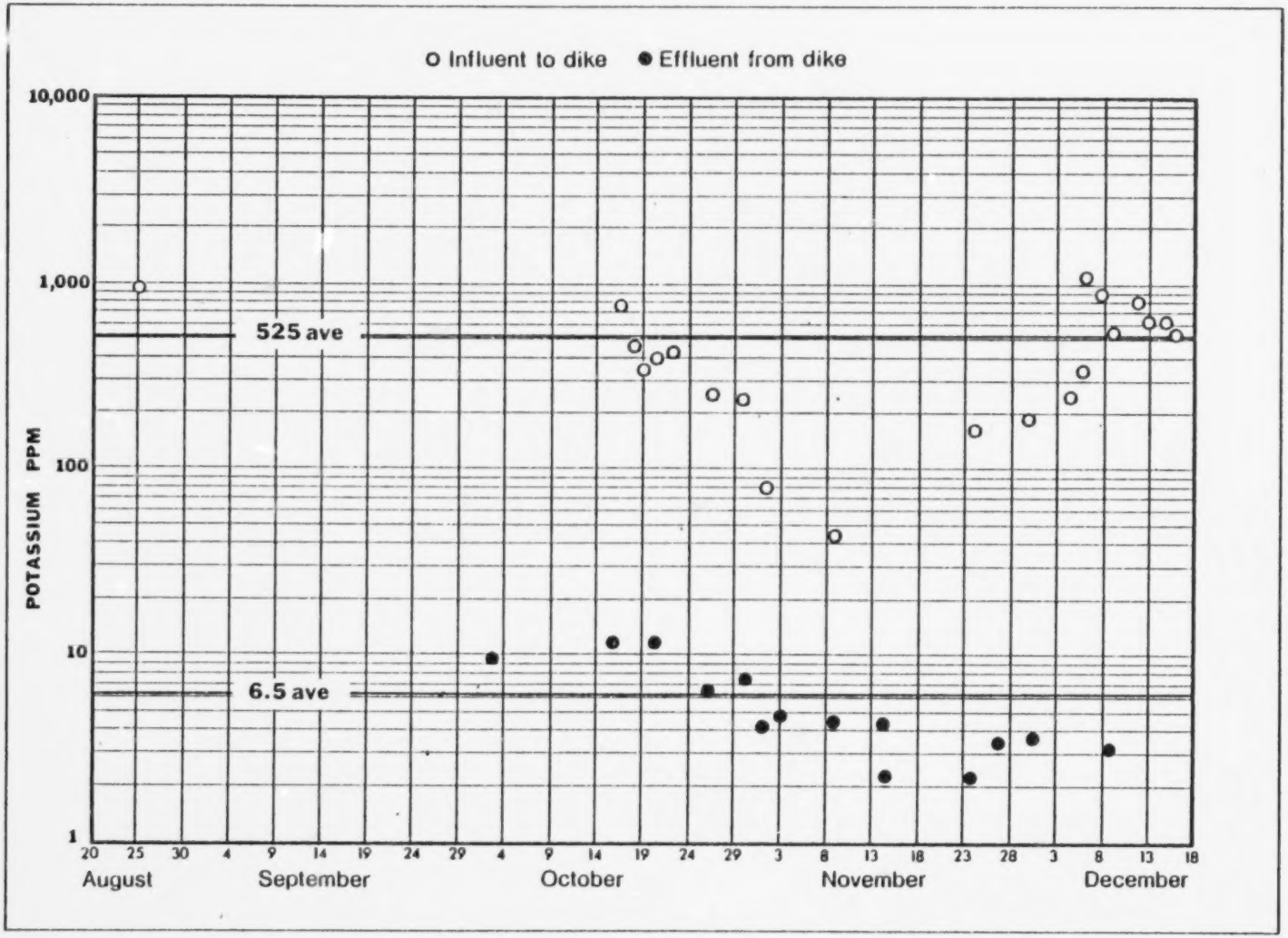


Figure D-14. Comparison of Influent-Effluent Quality for Potassium

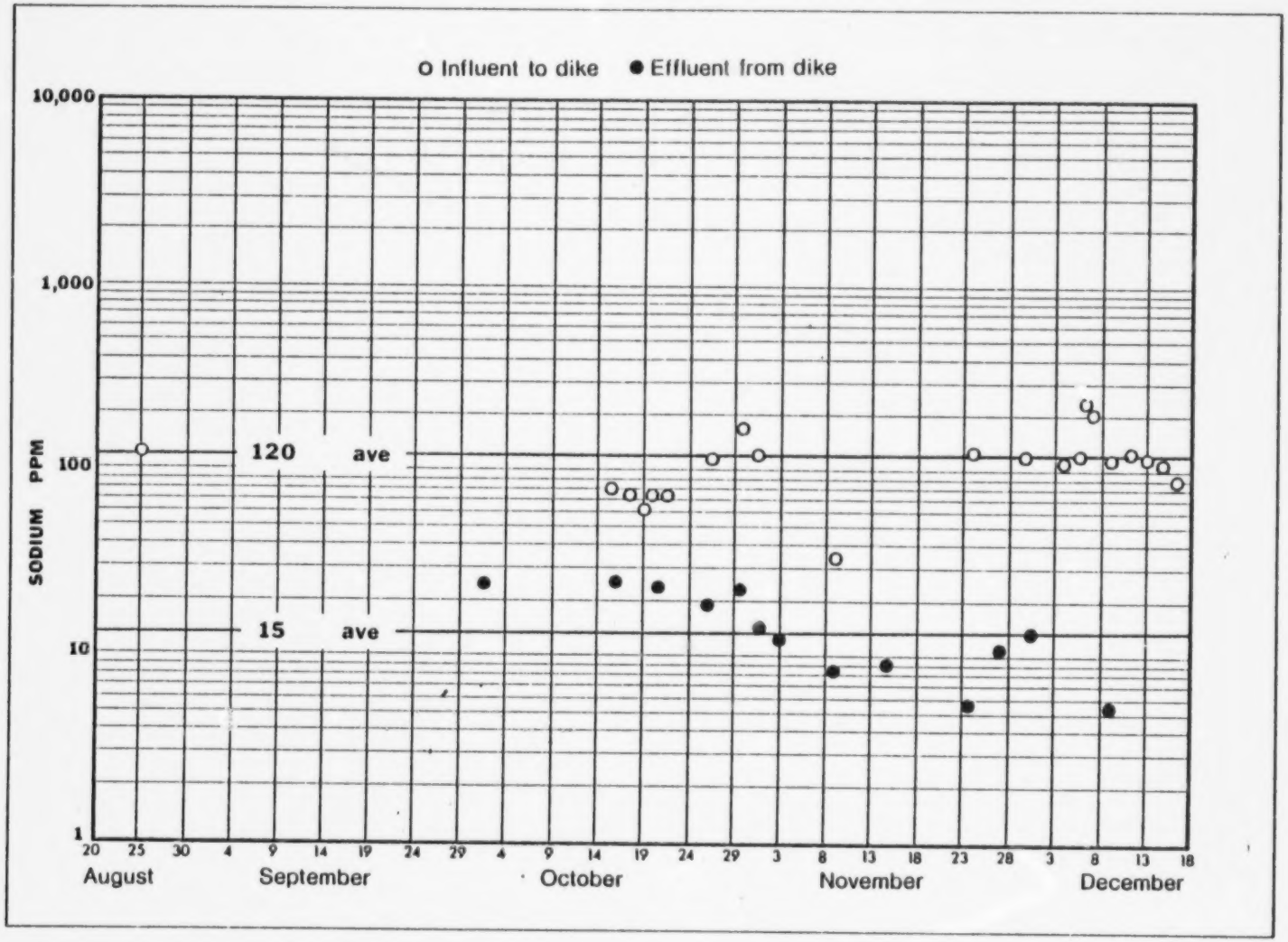


Figure D-15. Comparison of Influent-Effluent Quality for Sodium

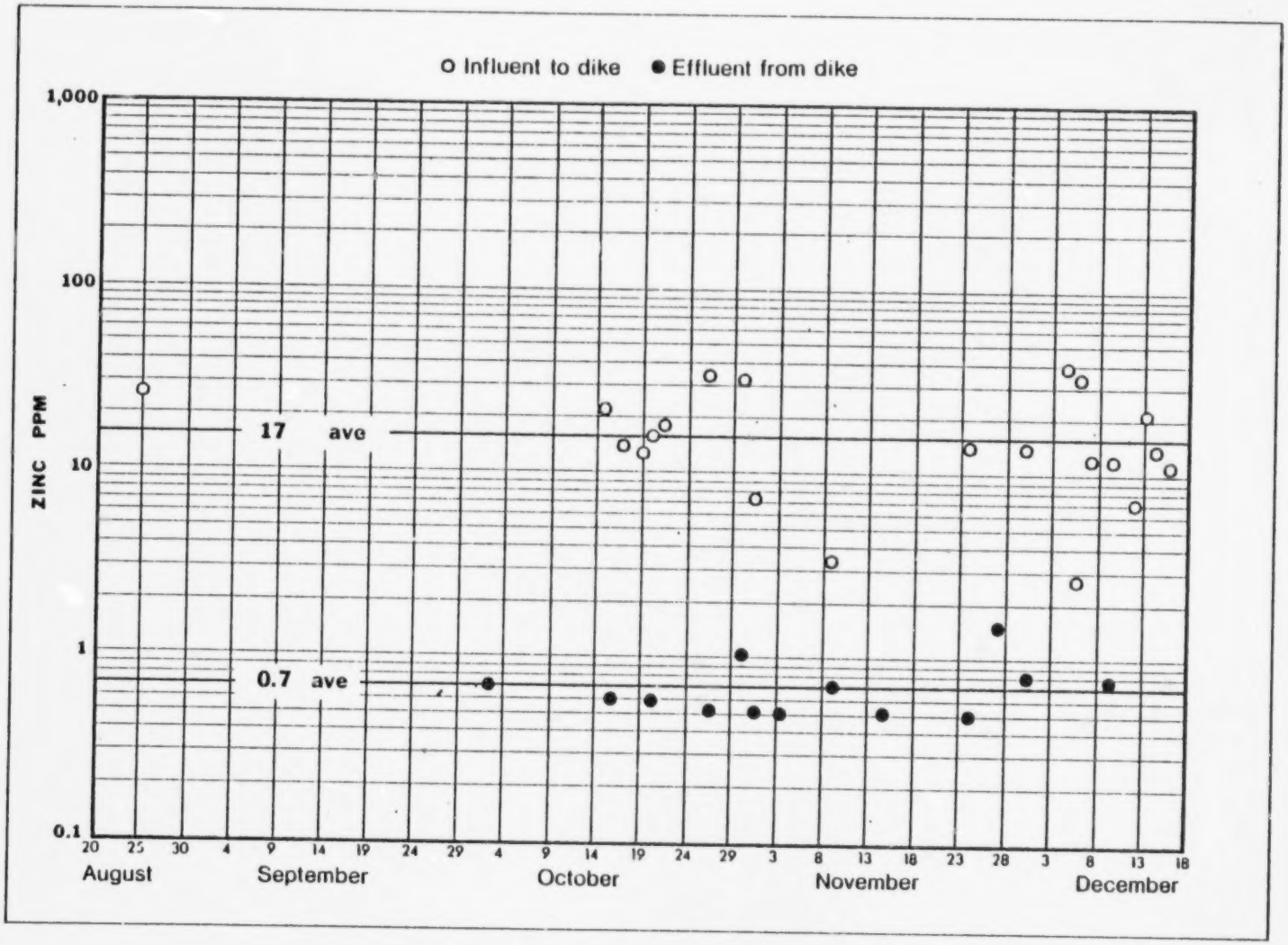


Figure D-16. Comparison of Influent-Effluent Quality for Zinc

APPENDIX E

RESULTS OF CHEMICAL AND BACTERIOLOGICAL ANALYSES ON GROUNDWATER SAMPLES AND INFLUENT SAMPLES

Independent chemical and bacteriological analyses were conducted on several series of groundwater, influent-effluent, and river samples taken at various times between 1972 and 1975. The results of standard tests for total and/or fecal coliform organisms are summarized in Tables E-1 through E-5, and the data from the chemical analyses are presented in Tables E-6 and E-7. All of these tests, except those reported in Tables E-4 and E-5, were performed by personnel of Limnetics, Inc. of Milwaukee, Wisconsin.

The data tabulated in Tables E-1 and E-6 were obtained from samples of groundwater taken on August 2 and 3, 1972 from wells located in Penn 7 disposal area before any dredgings were deposited. On August 25, 1972 samples of the influent slurry were taken from the end of the discharge pipe, and the results of the tests on these samples are given in Tables E-2 and E-7. Samples of groundwater, river water, influent slurry, water from the overflow weir, and stagnant water and mud from inside the disposal area were taken on August 1, 1973, when the site was about one-half filled with dredge spoil, and the associated bacteriological test data are summarized in Table E-3. What was intended to be the final series of groundwater samples was taken from the wells on August 22, 1974, after the site had been filled for almost a year, and the results of bacteriological analyses are given in Table E-4; however, due to analytical problems the results reported in Table E-4 are suspect (although not necessarily erroneous). Hence, another set of groundwater samples from the functional wells was obtained and tested on February 6, 1975, after the site had been filled for over a year. and the data are presented in Table E-5.

Table E-1

Baseline Bacteriological Data for Groundwater Samples
(August 2, 1972)

Sample	Location	Depth (feet)	Total Coliforms (organisms per 100 ml)	Fecal Coliforms (organisms per 100 ml)
A26TO	8/8	20	700	<1
A28TO	6/10	20	200	<1
A30TO	9/10	20	40	<1
A32TO	9/14	20	120,000	5,700
A34TO	9/14	10	24,000	580
A36TO	12/14	10	32,000	168

Table E-2

Bacteriological Data for Influent Slurry Samples
(August 25, 1972)

Sample	Total Coliforms (organisms per 100 ml)	Fecal Coliforms (organisms per 100 ml)
C29TO	800,000	46,000
C31TO	600,000	57,000
C34TO	680,000	23,000
C35TO	650,000	32,000
C38TO	2,000,000	60,000

Table E-3

Bacteriological Data for Various Water and Slurry Samples
(August 1, 1973)

Sample	Tube Method (T) or Membrane Method (M)	Total Coliforms		Fecal Coliforms	
		Determination (organisms per 100 mℓ)	Confidence Limit (tube test only)	Determination (organisms per 100 mℓ)	Confidence Limit (tube test only)
A73TO	(M)	5,500		56	
A74TO	(T)	11,000	1,500-48,000	11,000	1,500-48,000
A75TO	(M)	100		15	
A76TO	(T)	2,400	360-13,000	2,400	360-13,000
A77TO	(T)	46,000	7,100-240,000	9,300	1,500-38,000
A78TO	(T)	11,000	1,500-48,000	2,400	360-13,000
A79TO	(M)	41,000		360	
A79TO	(T)	4,600	710-24,000	2,400	360-13,000
A80TO	(M)	83,000		1,200	
A81TO	(M)	70,000		330	
A82TO	(M)	210,000		270	
C116TO	(T)	24,000	3,600-130,000	9,300	1,500-38,000
C117TO	(T)	24,000	3,600-130,000	9,300	1,500-38,000
C118TO	(T)	165,000	25,000-720,000	69,000	10,650-360,000
C119TO	(T)	1,125,000	200,000-3,450,000	1,125,000	200,000-3,450,000

Table E-4

Bacteriological Data for Various Water Samples (August 22, 1974)

Sample	Total Coliforms (organisms per 100 mℓ)
A83TO	0
A84TO	0
A85TO	15
A86TO	50
A87TO	30
A88TO	700
A89TO	100

Table E-5

Bacteriological Data for Various Water Samples (February 6, 1975)

Sample	Total Coliforms (organisms per 100 mℓ)
A90TO	0
A91TO	0
A92TO	0
A93TO	500
A94TO	700
A95TO	500
A96TO	0

Table E-6

Baseline Chemical Analyses on Groundwater Samples (August 2, 1972)

Parameter	Units	A27TO	A29TO	A31TO	A33TO	A35TO	A37TO
Total Solids	%	0.116	0.120	0.147	0.381	0.294	0.451
Nonvolatile suspended	%	0.034	0.040	0.024	0.189	0.133	0.278
Nonvolatile dissolved	%	0.026	0.030	0.052	0.096	0.073	0.064
Volatile suspended	%	0.023	0.003	0.043	0.056	0.037	0.062
Volatile dissolved	%	0.032	0.048	0.029	0.039	0.050	0.048
Turbidity	JTU	>500	>500	>500	>500	>500	>500
Color		15	20	20	6	65	4
pH		7.5	7.5	7.2	8.2	8.0	8.3
Silica	%	0.041	0.040	0.045	0.137	0.064	0.176
Total Alkalinity	mg/l	510.2	723.6	652.4	619.8	903.7	578.1
Hydroxide		0	0	0	0	0	0
Carbonate		0	0	0	0	0	0
Bicarbonate	mg/l	510.2	723.6	652.4	619.8	903.7	578.1
Total Phosphate	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ortho-phosphate	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Poly-phosphate	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total N	mg/l	21.54	14.50	16.70	5.72	18.71	2.14
NH_3-N	mg/l	21.54	14.50	16.70	5.72	18.71	2.14
NO_2-N	ppm	<0.01	<0.01	<0.01	0.05	0.07	0.025
NO_3-N	ppm	<2	<2	<2	<2	<2	<2
BOD	mg/l	<1	<1	<1	2	3	<1
Calcium	ppm	110	122	140	83	126	197
Chromium	ppm	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	ppm	<10	<10	<10	<10	<10	<10
Iron	ppm	60	57	67	82	66	109
Sodium	ppm	9.6	17.3	21.0	96.6	123.0	44.7

Table E-7

Chemical Analyses on Influent Slurry Samples (August 25, 1972)

Parameter	Units	C29TO	C31TO	C34TO	C35TO	C38TO
Total Solids	%	23.20	28.16	12.24	33.10	17.49
Nonvolatile suspended	%	15.98	25.911	11.173	30.734	15.950
Nonvolatile dissolved	%	0.028	0.039	0.031	0.036	0.032
Volatile suspended	%	1.214	2.161	1.013	2.267	1.477
Volatile dissolved	%	0.025	0.049	0.024	0.063	0.034
Silica	%	11.391	19.918	8.313	22.984	11.579
Total Phosphate	ppm	0.4	1.4	0.4	0.5	0.8
Ortho-phosphate	ppm	0.25	1.1	0.15	0.25	0.45
Poly-phosphate	ppm	0.15	0.3	0.25	0.25	0.35
Total N	mg/l	107.0	161.9	95.1	196.1	115.0
NH_3-N	mg/l	81.5	104.7	67.7	122.5	56.1
NO_2-N	ppm	14.4	1.5	10.3	1.4	18.8
NO_3-N	ppm	42.5	26.3	22.5	36.3	37.5
BOD	mg/l	320	350	380	370	340
COD	mg/l	25,000	36,700	27,000	36,500	25,500
Oil/grease	%	0.202	0.194	0.313	0.167	0.100
Cadmium	ppm	<5	<5	<5	<5	<5
Calcium	ppm	5260	5530	2830	4910	4050
Copper	ppm	<30	<30	<30	<30	<30
Iron	ppm	5550	5820	4140	5420	5720
Lead	ppm	14	12	<10	13	<10
Manganese	ppm	76	91	64	97	71
Potassium	ppm	974	1018	674	1213	790
Sodium	ppm	97	122	191	54	87

APPENDIX F

RESULTS OF GAS CHROMATOGRAPH TEST ON INFLUENT SAMPLE

A gas chromatographic analysis with electron capture detection was used to study the chlorinated hydrocarbon content of influent sample C38TO. A 500 ml aliquot of the sample was allowed to settle for several days (refrigerated) and the supernatant was decanted. The solids portion was dried by use of an infrared lamp oven, yielding 191.6 gms/liter solids. The supernatant water phase was extracted with hexane by a separatory funnel technique, and the dry solids were hexane extracted by means of a Soxhlet extractor method; both extracts were concentrated with a Kuderna-Danish concentrator. The gas chromatographic analyses were performed on a Perkin-Elmer model 900 chromatograph with a tritium foil electron capture detector; operating conditions are given on the attached chromatograms.

Figure F-1 shows the results of the supernatant water extract analysis. Several small traces of chlorinated organic compounds are indicated and appear to be in the 0.50 micrograms per liter (ppb) range. Figure F-2 indicates the chlorohydrocarbon content of the dried solids phase extract. The components present show an excellent match to the PCB mixture known commercially as Aroclor 1254. The concentration of this material in the original sample calculates to be 100 micrograms per liter (ppb) and 522 micrograms per kilogram (ppb) on a dry solids basis. Figure F-3 shows a chromatogram of the standard Aroclor 1254 polychlorinated biphenyl.

Based on a single gas chromatography test of one influent sample, it appears that significant amounts of chlorinated organic compounds are present in dredged sediments. However, due to their insolubility, only a trace of these compounds was detected in the water portion of the slurry, and most of

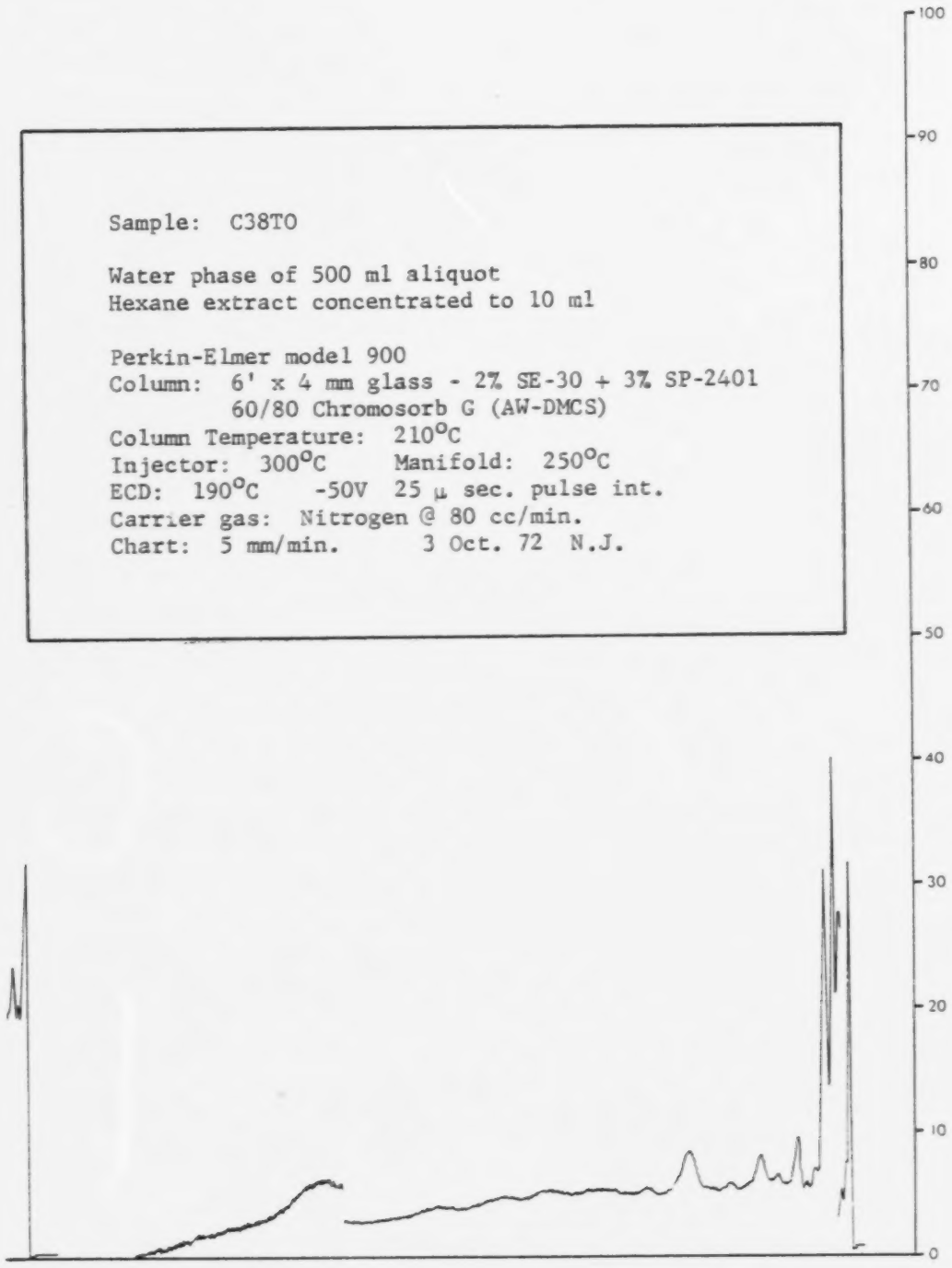


Figure F-1. Chlorinated Hydrocarbon Analysis of Water Phase of Dredging Sample

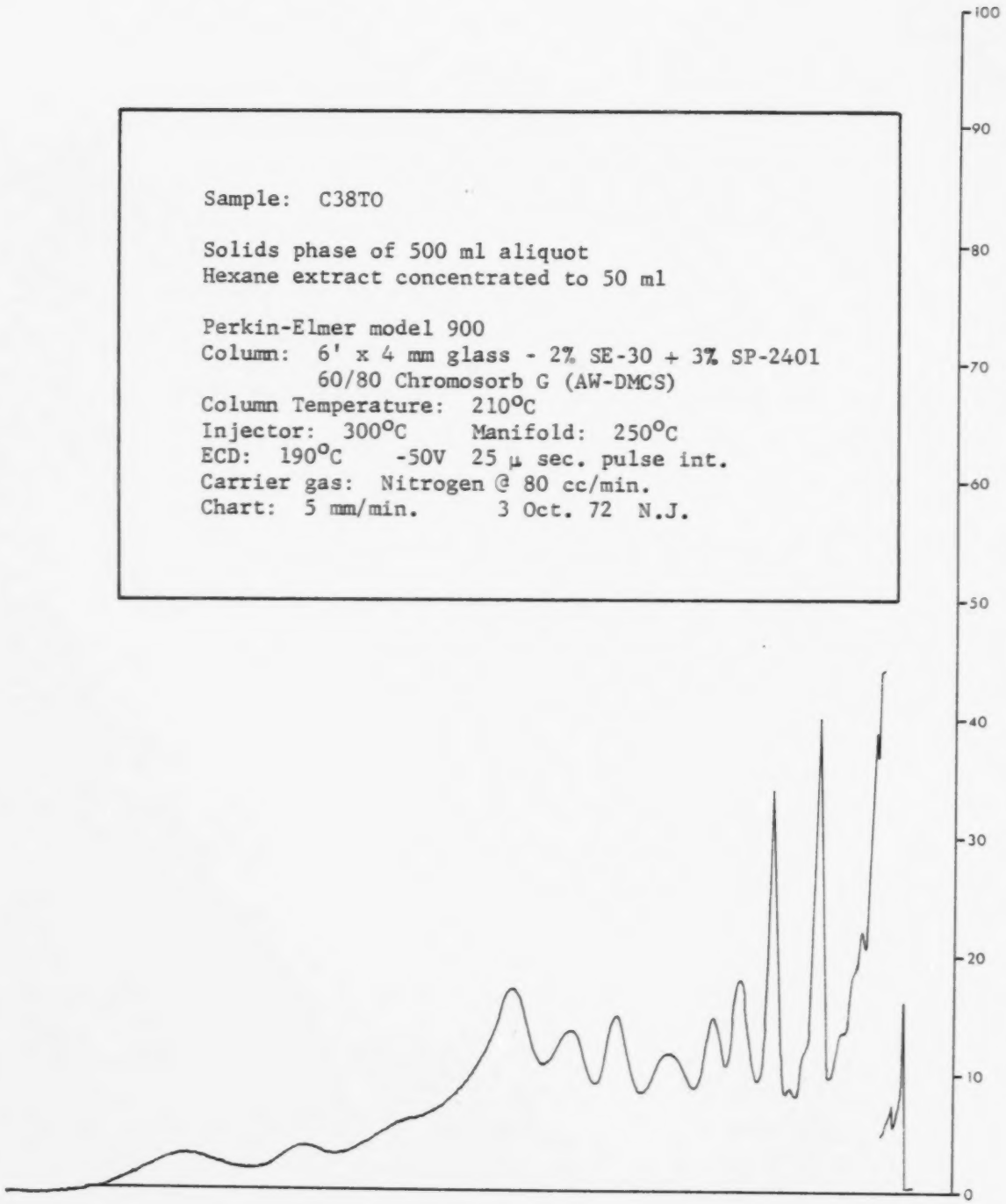


Figure F-2. Chlorinated Hydrocarbon Analysis of Solid Phase of Dredging Sample

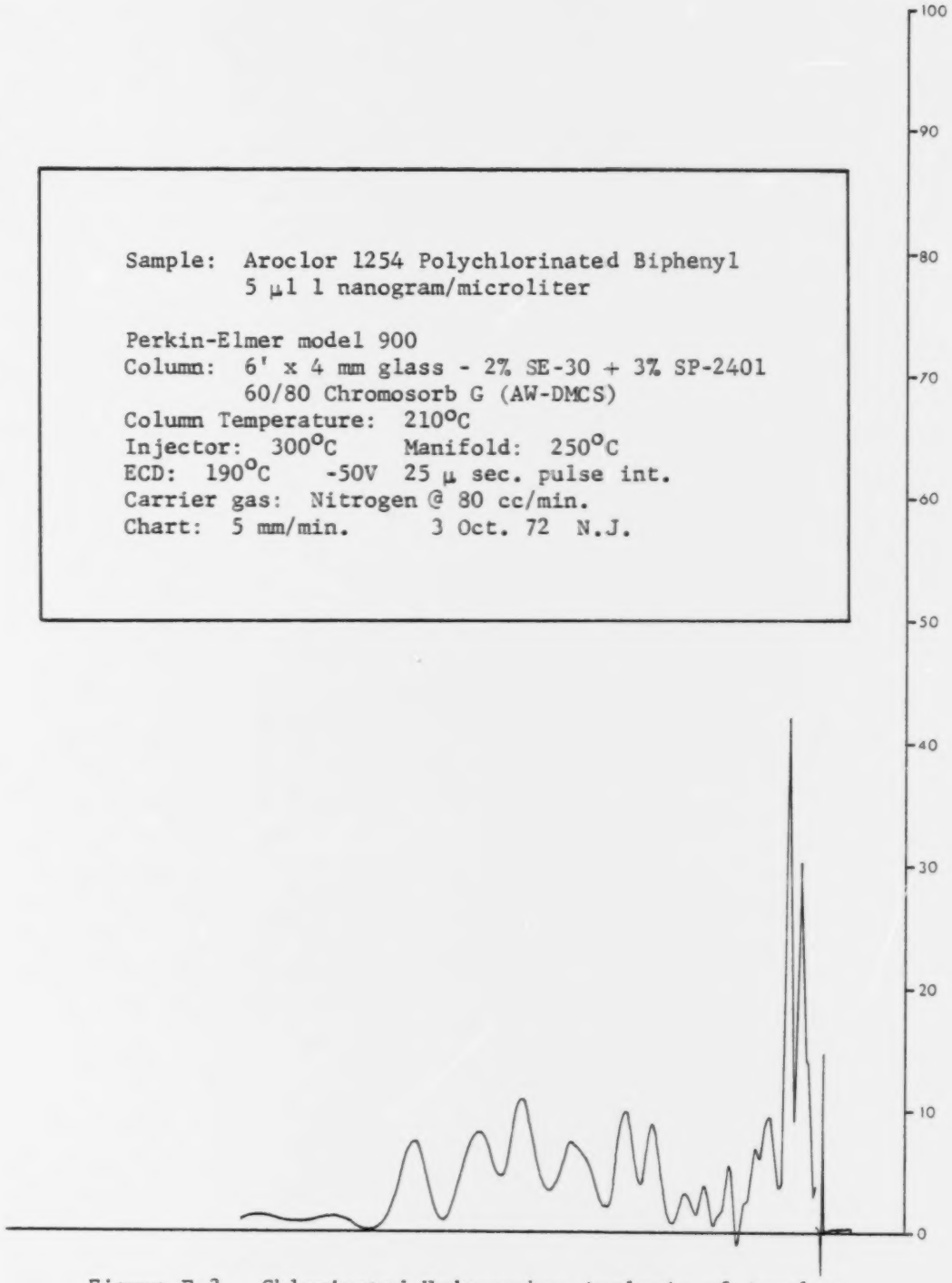


Figure F-3. Chlorinated Hydrocarbon Analysis of Aroclor 1254 Polychlorinated Biphenyl

the chlorohydrocarbon material is associated with the suspended solids. By comparison, the EPA proposed standard limits for drinking water content for most chlorinated pesticides is 10 ppb.

APPENDIX G

PRECIPTATION-EVAPORATION DATA

Table G-1 summarizes the daily values determined for the precipitation and evaporation during the period from August 20 to December 20, 1972. Since the evaporimeter became unusable on November 5, 1972, due to freezing temperatures, the evaporation data from this date until the termination of the field experiment were estimated. Also included in Table G-1 are the daily net water input and the accumulative input for the duration of the study. Of particular interest in the analysis reported herein is the net accumulative input during the period from October 19 to November 13, 1972; subtracting the October 19 accumulative input of 1.59 inches from the November 13 accumulative input of 4.19 inches yields a net accumulative input of 2.60 inches during this latter period.

Table G-1

Precipitation-Evaporation Data

Date: August	Precipitation (inches)	Evaporation (inches)	Net Input (inches)	Accumulative Input (inches)
20	0	.075	-.075	-.075
21	0	.075	-.075	-.150
22	0	.059	-.059	-.209
23	0	.059	-.059	-.268
24	.11	.067	+.043	-.225
25	0	.075	-.075	-.300
26	.23	.071	+.159	-.141
27	0	.051	-.051	-.192
28	0	.071	-.071	-.263
29	0	.087	-.087	-.350
30	0	.118	-.118	-.468
31	0	.118	-.118	-.586

Table G-1 (continued)

Precipitation-Evaporation Data

Date: September	Precipitation (inches)	Evaporation (inches)	Net Input (inches)	Accumulative Input (inches)
1	0	.055	-.055	-.641
2	.19	.020	+.170	-.471
3	0	.020	-.020	-.491
4	0	.031	-.031	-.522
5	0	.031	-.031	-.553
6	0	.043	-.043	-.596
7	0	.043	-.043	-.639
8	.09	.024	+.066	-.573
9	0	.043	-.043	-.616
10	0	.043	-.043	-.659
11	.03	.024	+.006	-.653
12	.01	.008	+.002	-.651
13	.29	.028	+.262	-.389
14	.40	.051	+.349	-.040
15	0	.087	-.087	-.127
16	0	.071	-.071	-.198
17	.11	.059	+.051	-.147
18	.80	.039	+.761	+.614
19	.01	.039	-.029	+.585
20	0	.039	-.039	+.546
21	0	.031	-.031	+.515
22	0	.047	-.047	+.468
23	0	.031	-.031	+.437
24	.02	.028	-.008	+.429
25	.44	.031	+.409	+.838
26	.77	.012	+.758	+1.596
27	0	.012	-.012	+1.584
28	.29	.043	+.247	+1.831
29	.36	.039	+.321	+2.152
30	0	.031	-.031	+2.121

Table G-1 (continued)

Precipitation-Evaporation Data

Date: October	Precipitation (inches)	Evaporation (inches)	Net Input (inches)	Accumulative Input (inches)
1	0	.051	-.051	+2.070
2	0	.079	-.079	+1.971
3	0	.051	-.051	+1.920
4	.07	.067	+.003	+1.923
5	.05	.047	+.003	+1.926
6	.01	.016	-.006	+1.920
7	0	.024	-.024	+1.896
8	0	.039	-.039	+1.857
9	0	.091	-.091	+1.766
10	0	.083	-.083	+1.683
11	.02	.036	-.016	+1.667
12	.17	.024	+.146	+1.813
13	0	.028	-.028	+1.785
14	0	.043	-.043	+1.742
15	0	.051	-.051	+1.691
16	.04	.043	-.003	+1.688
17	0	.016	-.016	+1.672
18	.01	.051	-.041	+1.631
19	0	.043	-.043	+1.588
20	0	.039	-.039	+1.549
21	.14	.008	+.132	+1.681
22	.21	.008	+.202	+1.883
23	.66	.039	+.621	+2.504
24	0	.012	-.012	+2.492
25	0	.031	-.031	+2.461
26	0	.028	-.028	+2.433
27	.01	.028	-.018	+2.415
28	.06	.004	+.056	+2.471
29	.12	.008	+.112	+2.583
30	0	.051	-.051	+2.532
31	0	.047	-.047	+2.485

Table G-1 (continued)

Precipitation-Evaporation Data

Date: November	Precipitation (inches)	Evaporation (inches)	Net Input (inches)	Accumulative Input (inches)
1	.12	.016	+.104	+2.589
2	.65	.051	+.599	+3.188
3	0	.016	-.016	+3.172
4	.02	.020	0	+3.172
5	0	↑	-.020	+3.150
6	0		-.020	+3.130
7	.83		+.810	+3.940
8	.14		+.120	+4.060
9	0		-.020	+4.040
10	0		-.020	+4.020
11	.23		+.210	+4.230
12	0		-.020	+4.210
13	0		-.020	+4.190
14	1.34		+1.320	+5.510
15	.06		+.040	+5.550
16	0		-.020	+5.530
17	.05		+.030	+5.560
18	0	Estimated	-.020	+5.540
19	0		-.020	+5.520
20	.40		+.380	+5.900
21	0		-.020	+5.880
22	.01		-.010	+5.870
23	.02		0	+5.870
24	0		-.020	+5.850
25	0		-.020	+5.830
26	.35		+.330	+6.160
27	0		-.020	+6.140
28	0		-.020	+6.120
29	0		-.020	+6.100
30	0	↓	-.020	+6.080

Table G-1 (continued)

Precipitation-Evaporation Data

Date: December	Precipitation (inches)	Evaporation (inches)	Net Input (inches)	Accumulative Input (inches)
1	0	.010	-.010	+6.070
2	.06		+.050	+6.120
3	0		-.010	+6.110
4	.15		+.140	+6.250
5	.20		+.190	+6.440
6	.82		+.810	+7.250
7	0		-.010	+7.240
8	.08		+.070	+7.310
9	.01		0	+7.310
10	.06	Estimated	+.050	+7.360
11	0		-.010	+7.350
12	.24		+.230	+7.580
13	.75		+.740	+8.320
14	0		-.010	+8.310
15	0		-.010	+8.300
16	.18		+.170	+8.470
17	0		-.010	+8.460
18	0		-.010	+8.450
19	0		-.010	+8.440
20	.21		+.200	+8.640

APPENDIX H

CALIBRATION OF WEIR

The general configuration of the overflow weir and its cylindrical housing is shown in Figure H-1. A series of tests were conducted on November 15, 1972 to determine the calibration coefficient, C, for this weir in order to calculate the flow quantity, Q, passing over it for a known crest height, H. In these calibration tests the outflow pipe was temporarily blocked, thereby allowing the cylindrical housing structures of diameter, D, to fill up to a known height, Δh; and the time required for this known volume of water to pass over the weir was measured. Since it was impractical to completely seal the outflow pipe, this calculated flow rate had to be adjusted for leakage.

Based on a weir width, W, of 4.73 feet, a cylinder diameter of 5.83 feet, and a selected Δh value of 3.58 feet, the computed volume to be filled was 95.6 cubic feet. The outflow pipe was temporarily sealed with a removable wooden plate, and a stop watch was used to measure the time required to fill the indicated volume. Based on three trial tests (each requiring on the order of several minutes),the average flow rate, Q, was determined to be 2.71 cubic feet per second. The leakage rate of the cylindrical structure was estimated by filling the cylinder, then stopping the flow by blocking the weir, and measuring the time required for the volume of water to leak out through the imperfectly sealed outflow pipe. Based on a measured time of approximately 300 seconds, the rate of leakage was determined to be about 0.32 cubic feet per second. Therefore, the adjusted total flow rate for the calibration tests is the sum of the measured flow rate and the leakage rate, or 3.03 cubic feet per second for an average crest height of 3.67 inches. The discharge rate, Q,

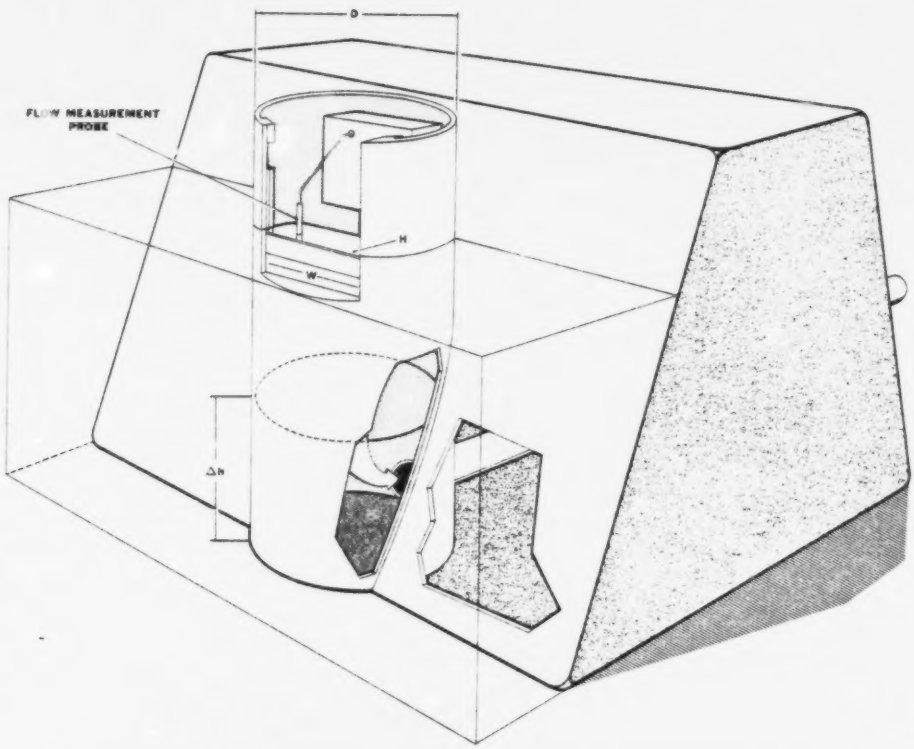


Figure H-1. General Configuration of Overflow Weir

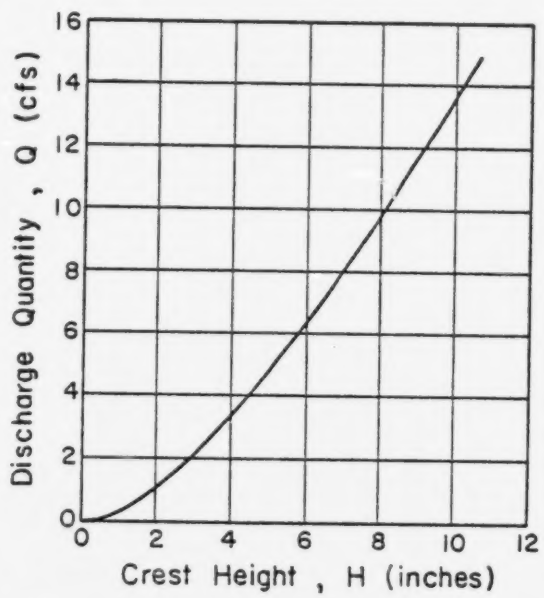


Figure H-2. Calibration Curve for Overflow Weir

over a rectangular weir can be calculated from

$$Q = CW\,H^{3/2} \qquad \text{(H-1)}$$

where Q is the discharge quantity in cfs, C is the calibration coefficient, W is the weir width, and H is the crest height. Solving Equation (H-1) for the calibration coefficient, C, and substituting the above mentioned values for Q, W, and H into the result, we obtain a value of 0.0914 $ft^2/sec/inches^{3/2}$ for the calibration coefficient, C. Use of this coefficient in conjunction with Equation (H-1) allows the flow rate, Q, to be determined as a function of the crest height, H, and the associated calibration curve is given in Figure H-2.

APPENDIX I

QUANTITY OF EFFLUENT WATER

Listed in Table I-1 are the average daily crest heights recorded at the overflow weir during the period from October 19 to November 13, 1972. When used in conjunction with the weir calibration curve given in Figure H-2, these average daily crest heights yield an average daily rate of discharge, q, and an average daily total discharge, Q, for each day. If the latter values are averaged over the 26 days during which measurements were taken, an average daily discharge of about 425,000 cubic feet is determined. Although it was desired to obtain discharge data for an additional month or so, the flow meter malfunctioned on November 13, 1972 and was rendered inoperable thereafter. The weekly low values of recorded discharge quantities are due to the cessation of dredging operations on Sundays. During these periods the crest of the overflow weir decreased due to the fact that water continued to flow out of the containment area while there was no input; when dredging and disposal operations resumed, the crest height and associated discharge quantity increased and remained relatively constant during the period of pumping.

Table I-1

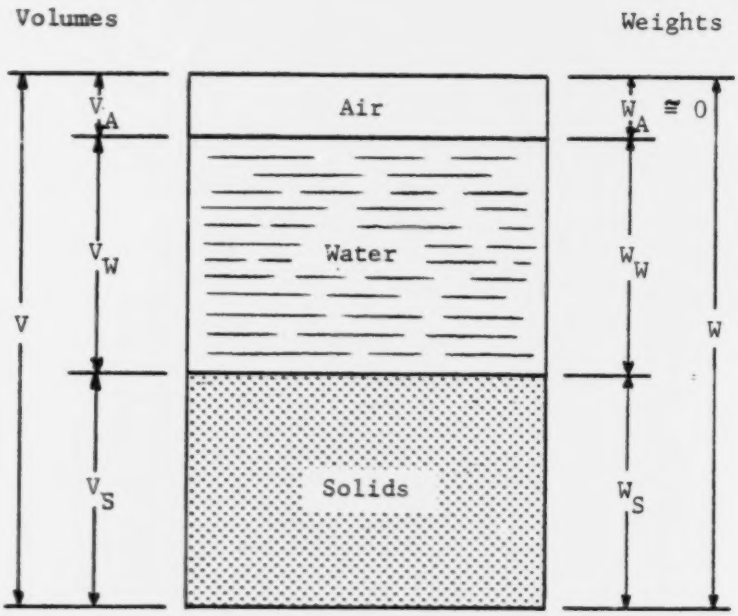
Outflow Discharge Data for Overflow Weir

Date	H_{avg} (inches)	q_{avg} (ft^3/sec)	Q_{total} (ft^3)
October 19	5.35	5.34	461,376
20	5.60	5.72	494,208
21	5.90	6.19	534,816
22	5.20	5.12	442,368
23	2.70	1.92	165,888
24	1.40	.72	62,208
25	2.15	1.36	117,504
26	3.10	2.36	203,904
27	3.30	2.59	223,776
28	3.75	3.14	271,296
29	3.96	3.40	293,760
30	2.67	1.88	162,432
31	4.75	4.47	386,208
November 1	6.10	6.51	562,464
2	6.70	7.49	647,136
3	7.00	8.00	691,200
4	6.70	7.49	647,136
5	5.56	5.66	489,024
6	3.50	2.83	244,512
7	6.00	6.35	548,640
8	6.90	7.83	676,512
9	6.85	7.74	668,736
10	7.05	8.09	698,976
11	7.00	8.00	691,200
12	4.99	4.82	416,448
13	3.50	2.83	244,512

APPENDIX J

QUANTITY OF INFLUENT WATER

Based on measured data and some reasonable assumptions, it is possible to estimate, but not quantify exactly, the average daily volume of water that was pumped into Penn 7 during the period from October 19 to November 13, 1972. These estimates can be determined by combining measured parameters at some stage of the dredging and disposal cycle with appropriate manipulations of the parameters defined in Figure J-1. The three stages in the cycle where the required information is reasonably well known are (a) the hopper of the dredge, (b) the end of the discharge pipe through which the dredging slurry is pumped into the disposal area, and (c) the disposal area itself. Corps of Engineer records indicate that the material in the hopper of the dredge (so-called bin measure volume) has a wet density, γ_w, of 1450 grams per liter (or 90 pounds per cubic foot); also, three samples (C84TO, C85TO, and C86TO; see Table C-3) taken by an Ekman dredge sampler from the hopper of the dredge gave an average value of 43.5% or 0.435 for the percent of solids, P_B, of the material in the dredge hopper. On the basis of 75 samples the percent of solids, P_D, of the slurry being pumped through the discharge pipe was found to be 14.9% or 0.149. Within the diked disposal area soon after sedimentation the dry density, γ_{dry}, has been quite well established to be about 50 pounds per cubic foot, and the Corps of Engineers empirical factor of 0.65 as a ratio of disposal site volume, V_D, to dredge bin measure volume, V_B, has been substantiated (Krizek and Giger, 1974); furthermore, on the basis of numerous tests the specific



Definitions:

Volume of Voids = $V_V = V_A + V_W$

Density of Water = γ_w

Porosity = $n = V_V/V$

Void Ratio = $e = V_V/V_S$

Degree of Saturation = $S = V_W/V_V$

Water Content = $w = W_W/W_S$

Percent Solids = $P = W_S/W$

Dry Density = $\gamma_{dry} = W_S/V$

Wet Density = $\gamma_{wet} = W/V$

Specific Gravity of Solids = $G_S = W_S/V_S\gamma_w$

Figure J-1. Phase Diagram of Dredging Sample

gravity of solids, G_S, has been found (Krizek, Karadi, and Hummel, 1973) to be about 2.7. Corps of Engineers records (Boresch, 1974) indicate that the average bin measure volume, V_B, deposited in Penn 7 during the period covered by this study was 85,000 cubic feet per day.

For purposes of this development, the disposal site volume, V_D, may be considered synonymous with the total volume, V; hence, we have

$$V_D = V = 0.65\ V_B \tag{J-1}$$

which, when combined with the definition for dry density, γ_{dry}, and the assumption of complete saturation and solved for V_S, yields

$$V_S = \frac{V\ \gamma_{dry}}{G_S\ \gamma_w} = \frac{0.65\ V_B\ \gamma_{dry}}{G_S\ \gamma_w} \quad . \tag{J-2}$$

In an analogous fashion, the following expression for V_S may be developed in terms of the average percent solids, P_D, of the slurry:

$$V_S = \frac{P_D}{1 - P_D} \frac{V_W}{G_S} \tag{J-3}$$

With the knowledge that all solids deposited in the containment area passed through the discharge pipe, Equations (J-2) and (J-3) may be equated and the result rearranged to give the volume of water, V_W, that entered the site:

$$V_W = \frac{0.65\ V_B\ \gamma_{dry}}{\gamma_w} \left(\frac{1 - P_D}{P_D}\right) \quad . \tag{J-4}$$

The volume of input water given by Equation (J-4) represents a minimum quantity because it does not account for the unknown volumes of water frequently pumped into the disposal area before and/or after each load in order to flush the system. Substituting into Equation (J-4) the

known values for V_B, γ_{dry}, γ_w, and P_D associated with the conditions described, we get

$$V_W = \frac{0.65(85{,}000\ ft^3/day)(50\ lb/ft^3)}{62.4\ lb/ft^3}\left(\frac{1 - 0.149}{0.149}\right) \cong 255{,}000\ ft^3/day \quad .$$

By similar reasoning for the volume of material, V_B, in the hopper of the dredge, the definitions for the percent of solids, P, and the wet density, γ_{wet}, may be combined to yield

$$V_S = \frac{\gamma_{wet}\ V_B\ P}{\gamma_w\ G_S} \quad , \qquad \text{(J-5)}$$

where V_B has been taken equal to V in this case, since the actual volume under consideration is the bin measure volume (or that volume in the hopper of the dredge). Since the volume of solids in the hopper of the dredge passed through the discharge pipe, Equations (J-3) and (J-5) can be equated and rearranged to give the volume of water, V_W, that entered the site as

$$V_W = \frac{\gamma_{wet}\ V_B\ P_B}{\gamma_w}\left(\frac{1 - P_D}{P_D}\right) \quad . \qquad \text{(J-6)}$$

The volume of input water given by Equation (J-6) should logically be higher than that given by Equation (J-4) because, although γ_{wet} represents the actual unit weight of the water-solids mixture, the value of P_B was measured for the sedimented solids (as sampled by an Ekman dredge) in the dredge hopper and does not reflect the supernatant water in the hopper; if this unknown volume of water were considered, P_B would be lower, and the input water would be correspondingly lower. Substituting into Equation (J-6) the known values for γ_{wet}, γ_w, V_B, P_B, and P_D, we obtain

$$V_W = \frac{90\ lb/ft^3\ (85{,}000\ ft^3/day)\ 0.435}{62.4\ lb/ft^3} \left(\frac{1 - 0.149}{0.149}\right) \cong 306{,}000\ ft^3/day \quad .$$

As with the result calculated from Equation (J-4), the above volume of water does not account for that associated with flushing the discharge pipe before and/or after the dredging slurry is pumped; hence, the actual volume of water pumped into the disposal area will be higher than either of these calculated values by some undetermined amount.

The daily influent water volumes of 255,000 and 306,000 cubic feet per day given by Equations (J-4) and (J-6), respectively, are both less than the average measured effluent volume of 425,000 cubic feet per day reported in Appendix I for this same time period. The accumulated precipitation-evaporation data given in Appendix G of the period from October 19, 1972 to November 13, 1972 indicates that a net precipitation equal to 2.60 inches was deposited over an area of approximately 1.34 million square feet; thus, about 11,000 cubic feet per day entered the disposal area by virtue of precipitation. Taking the larger of the calculated influent volumes and adding the precipitation volume, we have a calculated daily inflow of water equal to 317,000 cubic feet, which, when compared to the measured daily outflow of 425,000 cubic feet, yields a daily deficit of 108,000 cubic feet that must be deposited in the site by virtue of flushing the discharge pipe before and/or after each load (provided the undetermined amount of seepage into the underlying foundation soil is neglected).

Assuming an average of 8 loads per day and an average pumping time of 30 minutes for depositing only the dredgings (not the flush water) from each load (these figures are reasonably realistic for the Toledo area during the period of this test), 306,000 cubic feet of water plus

about 54,000 cubic feet of associated solids were pumped into the site in about 4 hours or 240 minutes; this gives a pumping rate of about 1500 cubic feet per minute. Using this pumping rate for the flushing phase of the operation, it would require about 72 minutes of flush pumping per day to account for the additional 108,000 cubic feet of water needed to balance the water budget. This reduces to about 9 minutes of flush pumping per load, which is quite reasonable. Even accounting for some seepage into the foundation soil, the required time for flush pumping would probably not be more than about 10 minutes. Hence, even though the exact volumes are not available to balance the water budget for the site, reasonable estimates yield a consistent qualitative and quantitative description of the process.